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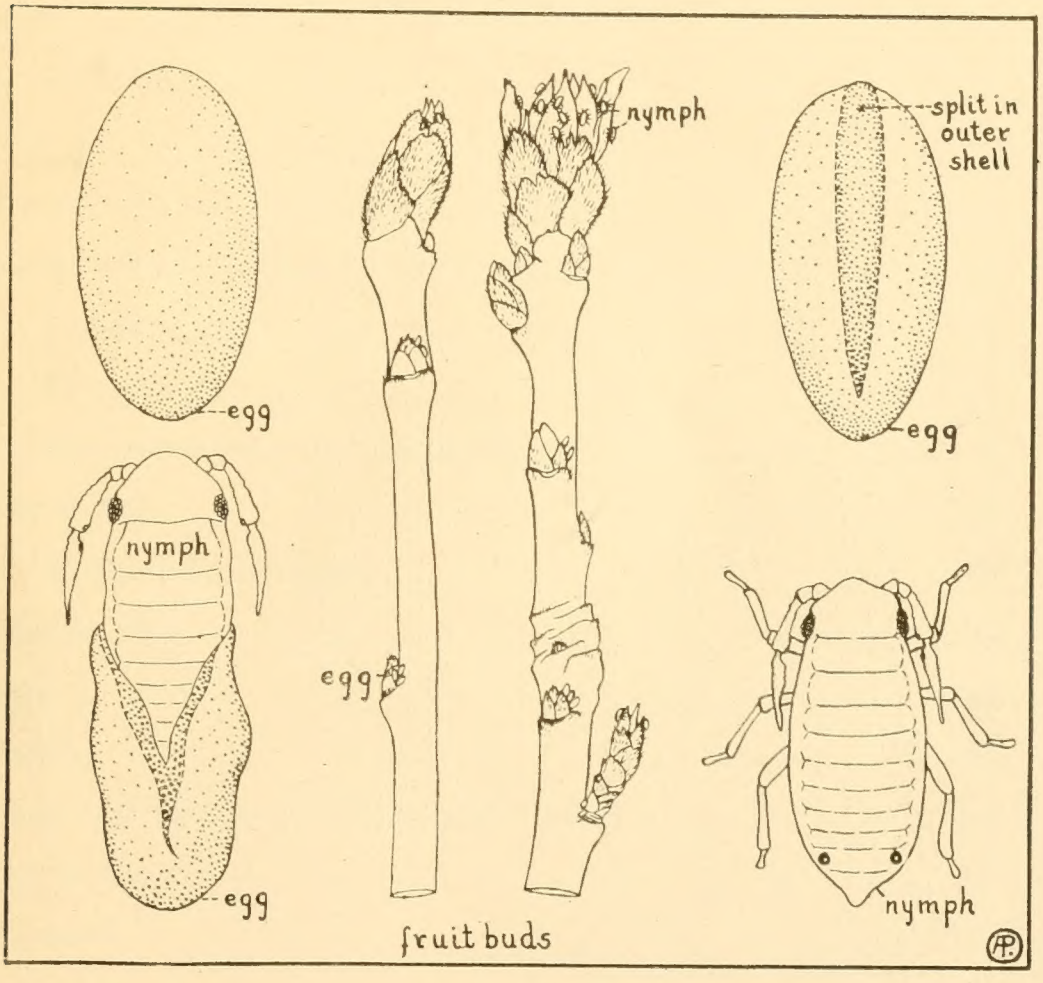

Time to Spray

SOME STUDIES ON THE EGGS OF IMPORTANT APPLE PLANT LICE

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NEW JERSEY
AGRICULTURAL EXPERIMENT STATIONS
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SOME STUDIES ON THE EGGS OF IMPORTANT APPLE PLANT LICE

By
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Introduction

This paper treats of some recent investigations on the structure, behavior and susceptibility of the eggs of three important aphides found on apple trees, *Aphis avenæ* Fabricius, *Aphis pomi* DeGeer, and *Aphis sorbi* Kaltenbach. It takes up a thorough discussion of the results obtained during the season of 1916-17 which were published in brief form in the *Journal of Economic Entomology* for December, 1917. It also includes a report on the extensive experiments and observations conducted during the past season (1917-18) on the eggs of *A. avenæ*.

A considerable amount of work has been conducted by various investigators on the effect of the more common contact insecticides on aphid eggs, but few if any good reasons have been advanced which explain the varying results. To get at the causes for these results involves a careful study of the physical and chemical structure of the egg, particularly the egg shell and the response of the egg to various stimuli such as temperature, moisture and chemicals. Studies pertaining to all these points have not been made, but some have been conducted, viz., the gross morphology of the egg coverings and their behavior previous to the emergence of the nymph, the susceptibility of the egg to variations in temperature and to different percentages of moisture, and the physical changes produced on the coverings of the egg by a number of common insecticides and other chemicals, and also the influence of these substances on the normal percentage of hatch.

The eggs of the three species of apple plant lice were collected from different orchards throughout the state of New Jersey during the past two seasons. In 1916-1917 the eggs of the so-called apple-bud-aphis, oat-aphis, or European grain-aphis, *A. avenæ*, were abundant in the orchards on the College Farm and at John H. Barclay's orchard, near Cranbury, N. J. During the same season the eggs of the rosy aphis, *A. sorbi*, also occurred in these orchards, but in no collection did they exceed 15 per cent of the total number. The

eggs of the green apple aphis, *A. pomi,* were very abundant on water sprouts in an old unkept orchard near Scott's corner, a few miles from Plainsboro, N. J., 1916-17. On May 1, some eight hundred stem mothers were collected from the water sprouts in this orchard and *A. pomi* made up 71 per cent of the total number, *A. sorbi* 26 per cent, and *A. avenæ* 3 per cent. This count, along with others, shows that *A. sorbi* probably made up 25 to 30 per cent of the total number of eggs.

During the past dormant season, 1917-18, the fall migrants and oviparous females were observed in a number of orchards throughout the state and in the majority of places *A. avenæ* was the only species present; *A. pomi* and *A. sorbi* were comparatively rare in most orchards. The investigations during the past season deal only with *A. avenæ.* Three orchards were chosen for supplying material: John H. Barclay's orchard, near Cranbury, N. J.; George Smith's orchard near South River, N. J.; and J. L. Lippincott Company's orchard, near Riverton, N. J.

All observations made in respect to the location of the eggs of the different species and the time of hatching conform closely with those made by Baker and Turner (2, 3) and other investigators. The eggs of *A. avenæ* and *A. sorbi,* for the most part are deposited under buds or in small crevices in the bark on second-year growth, and to some extent on larger branches, 2 inches in diameter, and occasionally on one-year growth. They are usually distributed evenly throughout the orchard. It has also been noted that varieties of apple trees which retain their leaves the longest in the fall of the year are apt to have the heaviest infestation. This is probably due to the fact that the oviparous female feeds on the under-side of the foliage and when the leaves fall from the tree she may disappear with the leaves, or if she is located on the branches of the tree when the leaves fall she is deprived of the opportunity to obtain food which is probably essential to the development of the greatest number of eggs. The eggs of *A. pomi* are deposited on one-year growth, particularly at the distal ends of water sprouts, and they are often scattered over the smooth surface of the twig. Usually the infestation is local, the eggs being confined to a few twigs on a tree and also not evenly distributed throughout the orchard. Frequently the eggs of *A. pomi* are very abundant in young orchards; this was true of John H. Barclay's orchard in 1915.

During 1917 the eggs of *A. avenæ* started to hatch about March 31, and, so far as observed, had completely hatched by April 6 or 7, while the eggs of *A. pomi* and *A. sorbi* started to hatch about April 12 to 14, and completed hatching in a week or ten days. *A. sorbi* apparently preceded *A. pomi* by two or three days, at least the stage of development of the nymphs after all eggs had hatched indicated

as much. In 1918 the eggs of *A. avenæ* started to hatch on March 21, and completed hatching on April 5. This early hatch was undoubtedly due to the unusually warm weather during March, 1918.

The percentage of eggs which hatch varies among the different species (compare the percentage of hatch in the different checks). Out of 1200 eggs of *A. avenæ,* 50 per cent hatched in 1917, while in 1918 only 30 per cent hatched out of 1800 eggs. The percentage of hatch in the different checks may vary considerably (25 per cent), when only a few eggs (50 to 100) are observed. The decided difference in the percentage of hatch for 1917 and for 1918 of this species is probably due to climatic conditions. The eggs of *A. pomi* and *A. sorbi* during 1916-17 were mixed together on the twigs used in the experiments (approximately 70 and 30 per cent, respectively), and this makes it impossible to determine the percentage of hatch for each, but out of 800 eggs in this mixture, the hatch was close to 25 per cent. The percentage of hatch for *A. pomi* is probably somewhat lower than that of *A. sorbi,* for the eggs of *A. pomi* are scattered promiscuously over the surface of the twigs and thus exposed to accident and to unfavorable weather conditions. The above percentages of hatch are considerably higher than those recorded by other investigators. Gillette, in Colorado, observed that only 1 per cent of the eggs of *A. pomi* hatched. This seems exceptionally low; however, environmental factors, such as a low percentage of humidity, may bring about this decided reeduction.

METHODS

All records in the table which pertain to the condition of the eggs, were made by carefully observing each egg under a binocular microscope and then noting whether it was normal, split, hatched or shriveled. In this way one can readily distinguish a normal egg by its plump and well rounded appearance and homogenous surface (plate 1, fig. 1), an egg with its outer semi-transparent covering split shows a distinct glossy black streak *p* usually along the mesodorsal line (plate 1, fig. 2 to 5), a hatched egg possesses a distinct opening in its surface (fig. 8 and 9), and a shriveled egg is dry and collapsed (plate 1, fig. 11 and 12).

During 1916-17 approximately 10,000 eggs were carefully observed, while in 1917-18 over 40,000 eggs were used in the various experiments, and a careful record was made for each egg. Whenever material was needed for experimental purposes, collections were made from the above-mentioned orchards and in all cases this material, when used for out-of-door experiments, was kept out-of-doors and exposed to all conditions of the weather, except for the few minutes required to examine the eggs under a

binocular microscope. Before starting or spraying any set of twigs, all eggs on each twig, 8-12 inches long, were carefully observed and their condition noted. If any egg was shriveled or hatched or appeared to be abnormal in any respect, it was removed; thus in the various experiments only normal-appearing eggs were used. Every twig bearing five or more normal eggs (in exceptional cases 200 eggs of *A. pomi* were present on one small twig) was given a string tag, and on this tag was written the number of the experiment, the source of the material, the treatment given, the number of normal eggs at the beginning of the experiment and in many cases the number of discarded abnormal eggs, and hatched eggs, if such were present.

The various common contact insecticides, lime-sulfur, miscible oils, laundry and fish-oil soaps, nicotine sulfate and nicotine resinate, and other chemicals such as crude carbolic acid, phenol c. p., meta cresol c. p., ortho cresol c. p., para cresol c. p., sodium hydroxide, sodium chloride, sodium sulfo-carbonate, pyridine solution, etc., were applied to the twigs by means of a small atomizer which was connected with a foot pump. The atomizer gave a coarse spray and the force of the spray was weak, for the greatest pressure could not throw the material over three feet. The twigs at the time of spraying were held a few inches from the tip of the atomizer, and, so far as possible, all sides of the twig and all the eggs were hit with the spray. Probably not one egg out of a thousand was missed.

Experiments with the various contact insecticides and chemicals during 1916-17 were conducted in the greenhouse on the eggs of *A. avenæ*, and out-of-doors with the eggs of all three species. In 1917-18 a duplicate set of experiments was started in the greenhouse and out-of-doors with the eggs of *A. avenæ*, but a shortage of coal during the month of February made it necessary to close the greenhouse. The twigs were brought into the laboratory from the greenhouse and placed in a large tin compartment, but the results obtained from these experiments were not as satisfactory as they would have been under greenhouse conditions, consequently they have been largely omitted from this paper. Since it was necessary to close down the greenhouse, a more strenuous effort was made to run a larger number of experiments under out-of-door conditions. The twigs used in the experiments in 1916-17 in the greenhouse were placed in tumblers and these were set on tanglefoot paper in order that the nymphs might not escape. The temperature of the greenhouse averaged 65° F., and the humidity was about 75 per cent most of the time. In all the out-of-door experiments conducted at the laboratory the twigs bearing the eggs were suspended on wires which extended across the tops of large empty wooden boxes. These boxes were located in an open place near the laboratory and completely exposed to all conditions of the weather, thus duplicating, as nearly as possible, the orchard environment. The results

from this laboratory method were very satisfactory during both seasons for they exactly duplicated the results obtained in the orchard where lime-sulphur, lime-sulphur combined with nicotine, and "Scalecide" were used. The loss of eggs in handling the twigs usually did not exceed 10 per cent, and in most cases it was less than 10 per cent. When a few eggs were lost, it is assumed that the loss was proportionally shared by eggs which would hatch under normal conditions and those that would not hatch.

MORPHOLOGY AND BEHAVIOR OF THE EGG

The eggs of *A. avenæ*, *A. pomi* and *A. sorbi* are glossy black, oval in form and slightly flattened on their ventral aspects, adjacent to the twig (plate 1, fig. 1 and 6). The eggs vary somewhat in size, but generally speaking they are about 1/45 inch in length and 1/90 inch in width. According to Baker and Turner (2) the eggs of *A. pomi* average 0.572 mm. by 0.281 mm., and of *A. sorbi* 0.550 mm. by 0.272 mm. The newly laid eggs are soft and retain this consistency, more or less, even after the outer shell hardens. A new egg has a light yellow color which soon changes to a green tinge and then gradually darkens to a deep black. This change usually takes place in a few days, one to four according to Baker and Turner. During the past season it was noted that a small percentage of the eggs of *A. avenæ* required ten or more days to change to a glossy black and some never changed, but retained their greenish tinge throughout the winter. Apparently these eggs are abnormal, for they did not hatch, so far as observed. Other abnormal eggs had a light brown tinge and they did not hatch.

The glossy appearance, particularly true of a newly deposited egg, is due to the moist glutinous layer which entirely surrounds it. This layer *t* hardens and glues the egg to the twig and also acts as a protective layer to conserve the moisture content of the developing embryo. After the outer layer hardens one can remove it by careful dissection, and then its thin, colorless, semi-transparent and somewhat tough consistency can be seen. This layer probably originates as a secretion from accessory glands in the oviparous female, at least such glands are present in the female.

The black or pigmented portion *p* of the egg is entirely confined to the slightly tough and elastic membrane directly beneath the outer semi-transparent layer. The glossy black and moist appearance of this layer is readily observed in eggs where the outer semi-transparent layer *t* has split (plate 1, fig. 2-10). The pigmented layer undoubtedly is a true chorion for it is found about the egg as a distinct pigmented layer when the egg has nearly completed its formation within the oviparous female. The chorion is secreted by the ovarian cells about the ovum. The pigmented layer may serve as a protective covering, but, so far as water conservation is concerned

and also as a protection against certain chemicals, it is of little use, as shown in various experiments.

A third layer, which is a thin transparent membrane, surrounds the nymph as it starts to emerge. This layer is shed by the nymph as it emerges, consequently it must be an exuvium. The cast skin *e* may be seen as a shriveled white mass at the cephalic end of the opening of a hatched egg.

The two layers of the egg and the skin about the nymph as it emerges undergo certain changes at the time of hatching, and these are significant, for they have an important bearing upon the response of the egg to differences in temperature and moisture and to common insecticides and other chemicals. These changes have been observed for two seasons on the eggs of all three species, but they have been observed with special care on the eggs of *A. avenæ*.

In 1917 it was noted that the semi-transparent outer layer *t* of many eggs of all three species splits (plate 1, fig. 4 and 5) along the meso-dorsal line a short time previous to the emergence of the young nymph. The split starts near the cephalic end (plate 1, fig. 4) and usually extends to the posterior end, and in nine cases out of ten occurs along the meso-dorsal line. In exceptional cases the outer layer *t* may show several breaks (plate 1, fig. 2 and 3), or the single split may not follow the meso-dorsal line (plate 1, fig. 9). The time interval between the splitting of the outer layer and the rupture of the pigmented layer was not definitely determined in 1917, for the significance of the splitting was not realized until it was too late to make the necessary observations. It was observed, however, that the eggs of *A. avenæ* under greenhouse conditions showed a split outer covering about 48 hours before any hatching occurred, while the eggs of *A. pomi* under out-of-door conditions showed a split outer shell some eight days before any hatching occurred. During 1918 the first split eggs of *A. avenæ* were seen on February 15. Just previous to this date we experienced a few warm days after a continuously cold and severe winter. From February 15 on, the percentage of eggs showing a split outer covering increased. The eggs were observed in batches of 200 to 500 collected from various orchards. The eggs collected from J. L. Lippincott Company's orchard at Riverton, N. J., showed the following increase in the percentage of eggs with split outer shells (kept out-of-doors) and these observations are typical of eggs collected from other orchards in 1918: February 19, 2 per cent split; February 26, 10 per cent split; March 1, 20 per cent split; March 4, 25 per cent split; March 11, 33 per cent split; March 19, 43 per cent split; and March 25, 47 per cent split (also see diagram 1). So far as observed, about 95 per cent of all the live eggs had broken their outer semi-transparent shell before the first nymphs emerged.

So far as is known, no egg hatched under out-of-door conditions without splitting its outer semi-transparent layer at least 48 hours before the nymph emerged. The above 47 per cent of split eggs observed on March 25 probably increased to 53-55 per cent before all the eggs hatched, at least other checks showed a total of 53 to 55 per cent of eggs with split outer coverings. This 53-55 per cent of eggs with split outer coverings shows that this percentage of eggs was normal, alive and preparing to hatch, but during the past season an average of 29 per cent of all the eggs actually hatched. In other words, 24 to 26 per cent of the eggs after splitting their outer covering were unable to complete the process of hatching.

Eggs of *A. avenæ* (200 collected from J. L. Lippincott Co.) were brought into the laboratory on February 26, 1918, and kept in a moist chamber (70° F.). The percentage of split eggs increased with great rapidity because of the increase in temperature over out-of-door conditions: on February 26, 10 per cent split; February 27, 23 per cent split; March 1, 25 per cent split, and 1 per cent hatched; March 6, 33 per cent split and 10 per cent hatched; March 11, 20 per cent split and 29 per cent hatched; March 13, 9.5 per cent split and 41 per cent hatched; and March 15, 7 per cent split and 43.5 per cent hatched. There was no increase in hatched or split eggs after March 15. The minimum period of time between the splitting of the outer covering and the emergence of the nymph under indoor conditions was not observed; however, so far as known all eggs split their outer shell at least a few hours before emergence.

In these indoor experiments only 28 per cent of the eggs showed a split outer covering when the first nymphs emerged. This means that only 55 per cent of the live eggs which were preparing to hatch had split their outer shell before the first nymphs appeared. This is quite different from the 95 per cent among the live eggs kept out-of-doors. Temperature, therefore, has a marked influence on the rapidity with which the nymph will emerge after the outer shell is broken. In the above indoor experiment it was also observed that 50.5 per cent of all the eggs split their outer shells and that 43.5 per cent of all the eggs hatched. In other words only 7 per cent of the eggs with split outer coverings failed to hatch, while 24 to 26 per cent of the eggs with split outer shells failed to hatch when kept out-of-doors. The explanation for this decided difference is probably due to differences in moisture (evaporating factors) as explained further on.

The splitting of the outer layer is probably due to the pressure exerted along the meso-dorsal line by the developing embryo or nymph. It is also possible that certain secretions may help to dissolve or weaken the brittle outer layer. A careful histological study may throw some light on this question. All eggs with a split.

EXPLANATION OF FIGURES

All figures are known to be typical of *A. avenæ* and *A. pomi* (and probably A. sorbi) unless otherwise designated.

Fig. 1—Dorsal view of a normal dormant egg.

Fig. 2 & 3—Dorsal views of eggs showing unusual types of splitting in the outer semi-transparent covering.

Fig. 4—Dorsal view of an egg showing an early stage in the usual type of splitting of the outer semi-transparent layer.

Fig. 5—Dorsal view of an egg showing an advanced stage in the usual type of splitting of the outer semi-transparent layer.

Fig. 6—Lateral view of egg seen in figure 5 showing the elevated inner pigmented layer, or chorion.

Fig. 7—Dorsal view of an egg of *A. avenæ* showing an early stage in the emergence of the nymph. Note the egg burster on the head of the nymph along the meson and the cut pigmented layer.

Fig. 8—Dorsal view of an empty egg shell showing usual method of splitting.

Fig. 9—Dorsal view of an empty egg shell showing unusual method of splitting.

Fig. 10—Dorsal view of a nymph of *A. avenæ* emerging from an egg; nymph about to free itself completely from the egg.

Fig. 11—Dorsal view of an egg partly shriveled.

Fig. 12—Dorsal view of an egg completely collapsed.

Fig. 13—Dorsal view of an egg, similar to figure 5, which has been sprayed with a 2 per cent solution of crude carbolic acid. Observe the wrinkled outer semi-transparent layer.

Fig. 14—Dorsal view of an egg, similar to figure 5, showing early stage in usual method of shrivel when egg has been treated with various sprays, particularly crude carbolic acid and miscible oils.

ABBREVIATIONS

ant. Antenna
b. Egg burster
d. Depression
e. Elevation
n. Nymph
p. Inner pigmented layer (chorion)
s. Split or opening in empty hatched eggs
t. Outer semi-transparent layer
v. Exuvium (?)

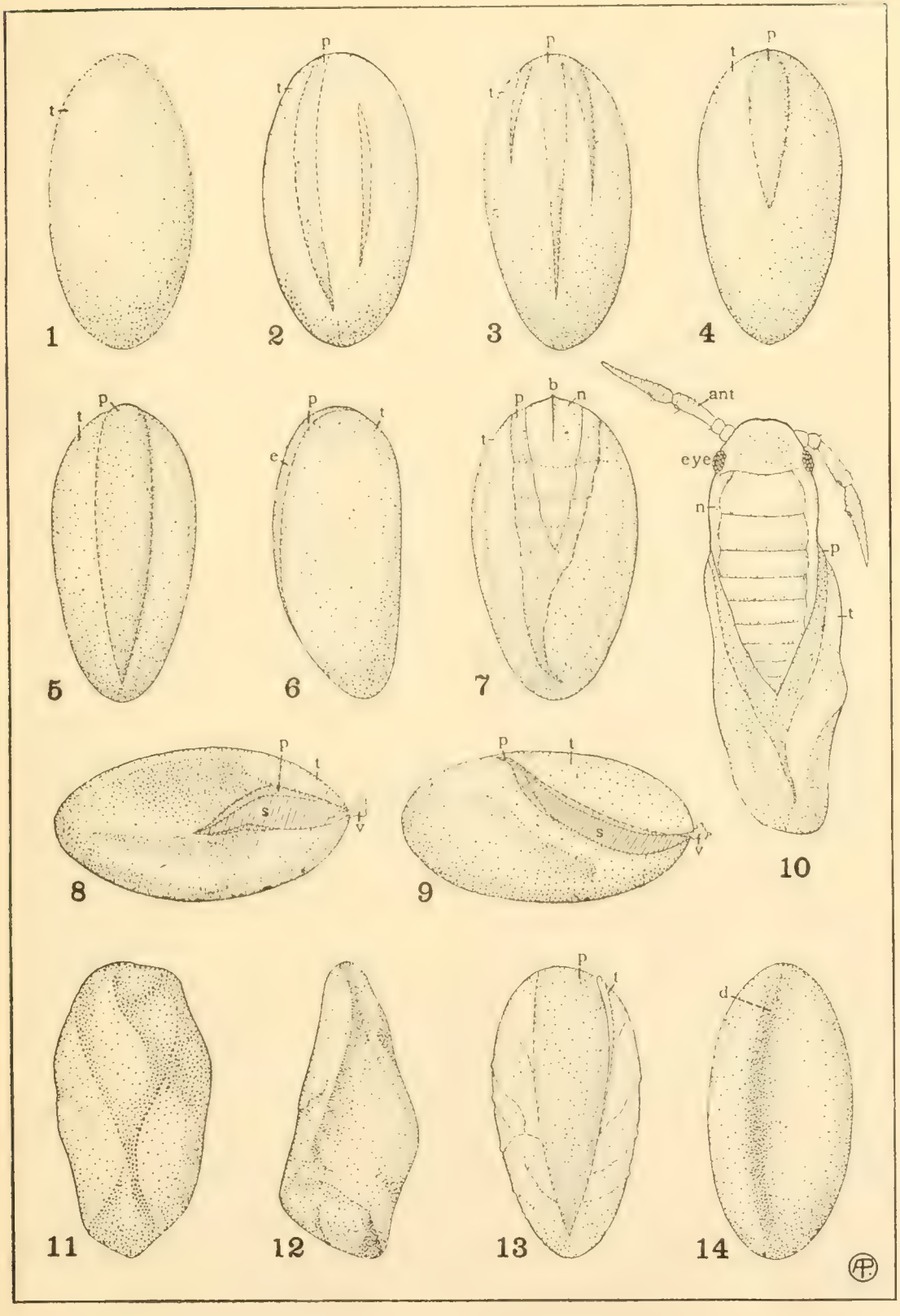

Plate 1. Eggs of *A. avenæ* and *A. pomi*.

outer, semi-transparent shell are readily distinguished from dormant eggs by the decided glossy black appearance of the exposed and unbroken pigmented layer *p*, while the portion of the egg covered with the semi-transparent shell has a duller black color. After the outer shell splits and when the young nymph is ready to emerge it exerts pressure along the meso-dorsal line and severs the pigmented layer (plate 1, fig. 7) with the sharp dark-colored ridge or egg burster *b* located along the meso-dorsal line of the head of the nymph.

The egg burster *b* was observed on the dorsal aspect of the head of *A. avenæ* and *A. pomi*. It coincides with the usual location of the stem of the epicranial suture. During emergence this ridge disappears and only a faint line remains along the meson. No egg burster was seen in the nymphs of *A. sorbi*, but this was probably due to the fact that the nymphs were not seen immediately after they cut their way through the pigmented layer. The origin and disappearance of the egg burster has not been carefully worked out, but it is possible that this ridge or cutting edge belongs to the exuvium or skin which seems to be shed by the nymph as it emerges. If such is the case this will account for its disappearance.

The pigmented layer which is severed by the nymph is somewhat elastic. This is shown in the fact that the egg is a trifle larger at the cephalic end after the outer layer splits. Also, the pigmented layer is elevated to a slight extent between the edges of the broken outer layer, as seen in figures 4, 5 and 6. This elevation is probably due to the pressure exerted by the nymph within the egg as it tries to cut its way out. The elasticity is also shown in hatched eggs, for the pigmented layer contracts somewhat after it is ruptured and the edges of this rupture often coincide with the margin of the broken semi-transparent outer covering (fig. 8 and 9). The wriggling and twisting of the nymph as it emerges may also help to push the pigmented layer back to the point where it coincides with the margin of the split outer shell.

As the nymph of *A. avenæ* starts to emerge it is covered with a thin transparent skin which it sheds before it is out of the shell. This skin is exceedingly thin and very difficult to see. The writer was unable to determine the exact time in the emergence period when the nymphs break this skin. If the egg burster belongs to this first exuvium it is shed a short time before the nymph reaches the stage shown in figure 10. This same membrane in *A. pomi* apparently is not shed until the nymph is almost out of the shell. Observations concerning the above point need to be repeated for all three species. The nymph of *A. avenæ* is usually two-thirds out of the egg before the appendages of the body become free and useful. The antennæ are the first to be free of the exuvium and the

legs come next, starting with the prothoracic. The last appendages to free themselves of the egg and exuvium are the metathoracic legs and mouth-parts. A distinct skin is withdrawn from the beak. This in part probably surrounded the maxillæ and mandibles. The process of hatching is apparently a difficult one, for many nymphs are unable to free their various appendages, especially the metathoracic legs which often remain attached to the white mass of skin at the cephalic end of the open egg. Numerous nymphs are thus killed in the very last stage of hatching. The above fate of many a nymph may be due to the fact that the exuvium hardens on long exposure to air and this makes it very difficult for the nymph to remove the last pair of legs.

The above detailed observations on the morphological structure of the egg and the behavior of the respective coverings during the hatching period (February 15 to April 5 for *A. avenæ)* shows conclusively that the egg is not a hard resistant body and that it goes through a critical change previous to the emergence of the nymph, which means that it is not as resistant during these changes as in the dormant period. It is in the midst of these changes or just previous to any visible change that certain control measures may produce their greatest effect. Some eggs start to split 30 to 35 days before the first nymphs appear, but the largest percentage of split eggs, 47 per cent or better, occurs at the time the first nymphs emerge (only 29 per cent of *A. avenæ* emerged this past season). In brief, the percentage of eggs showing a split outer shell is progressive and this is an important point when one wishes to obtain the best results with certain contact insecticides.

SUSCEPTIBILITY OF EGGS TO MOISTURE AND TEMPERATURE

Moisture

A few experiments have been conducted with the eggs of *A. avenæ* and *A. pomi* to determine the effect of different percentages of moisture on the hatching of the egg and the relative permeability of the two outer layers. The results of these few experiments are very suggestive and undoubtedly have an important bearing on the percentage of hatch which will occur under varying out-of-door conditions. They also throw considerable light on the problem of how certain contact insecticides may prevent hatching.

During 1917 experiments were conducted with different percentages of moisture in the incubators and moisture control apparatus used by Dr. T. J. Headlee in his investigations on grain-infesting insects; the writer wishes to express his appreciation for the privilege of using this efficient apparatus. The four incubators

TABLE 1

TABLE SHOWING EFFECT OF VARIATIONS IN MOISTURE ON EGGS OF A. AVENAE AND A. POMI AT A CONSTANT TEMPERATURE OF 80° F.

Expt. No.	Eggs of	Percentage of moisture	Started	Observed	Total Eggs	Total Hatch	Total Normal	Total Shriveled	Percentage of Hatch	Days Required to Shrivel Eggs Completely
101	*A. avenae*	Dry	Mar. 25	Mar. 27	25	1	10	14	4	3 days
				Mar. 28	25	1	0	24		
102	*A. avenae*	22	Mar. 25	Mar. 27	25	0	12	13	12	4 days
				Mar. 28	25	0	4	21		
				Mar. 29	25	3	0	22		
103	*A. avenae*	63	Mar. 25	Mar. 27	25	0	19	6	20	10 days
				Mar. 28	25	2	12	11		
				Mar. 29	25	3	7	15		
				Mar. 31	25	3	2	20		
				Apr. 4	25	5	0	20		
104	*A. avenae*	100	Mar. 25	Mar. 27	25	1	24	0	36	10 days
				Mar. 28	25	6	17	2		
				Mar. 29	25	7	14	4		
				Mar. 31	25	7	9	9		
				Apr. 4	25	9	0	16		
105	*A. pomi*	Dry	Apr. 6	Apr. 7	102	2	54	46	2	5 days
				Apr. 9	102	2	5	95		
				Apr. 11	102	2	0	100		
106	*A. pomi*	22	Apr. 6	Apr. 7	101	0	52	49	00	5 days
				Apr. 9	101	0	6	95		
				Apr. 11	101	0	0	101		
107	*A. pomi*	63	Apr. 6	Apr. 7	100	1	73	26	20	8 days
				Apr. 9	100	10	35	55		
				Apr. 11	100	18	5	77		
				Apr. 14	100	20	0	80		
108	*A. pomi*	100	Apr. 6	Apr. 7	100	3	95	2	46	8 days
				Apr. 9	100	45	28	27		
				Apr. 11	100	46	2	52		
				Apr. 14	100	46	0	54		
109	*A. pomi*	Dry	Mar. 14	Mar. 17	175	0	100	75	00	7 days
				Mar. 19	175	0	25	150		
				Mar. 21	175	0	0	175		
110	*A. pomi*	22	Mar. 14	Mar. 17	250	0	210	40	00	11 days
				Mar. 19	250	0	160	90		
				Mar. 21	250	0	50	200		
				Mar. 23	250	0	10	240		
				Mar. 25	250	0	0	250		
111	*A. pomi*	63	Mar. 14	Mar. 17	250	0	235	215	00	24 days
				Mar. 19	250	0	215	35		
				Mar. 21	250	0	195	55		
				Mar. 23	250	0	180	70		
				Mar. 25	250	0	150	100		
				Apr. 4	250	0	50	200		
				Apr. 7	250	0	0	250		
112	*A. pomi*	100	Mar. 14	Mar. 17	125	0	120	5	00	24 days
				Mar. 19	125	0	110	15		
				Mar. 21	125	0	100	25		
				Mar. 23	125	0	85	40		
				Mar. 25	125	0	35	90		
				Apr. 4	125	0	35	90		
				Apr. 7	125	0	0	125		

registered 80°F., and each was fitted with one moisture-control apparatus; one contained dry air which always registered less than 0.5 per cent moisture, another air of 22 per cent moisture, the third about 63 per cent moisture, and the fourth air completely saturated. Practically no variation occurred in the dry air and in the saturated, while in the case of 22 and 63 per cent moistures the amount occasionally fluctuated 1 to 5 per cent. The eggs were carefully selected and removed from the twigs by cutting the bark adjacent to them, or very small twigs bearing numerous eggs were chosen, and these placed in 80cc. glass bottles fitted with rubber stoppers having two short glass tubes which connected the bottle with the moisture-control equipment.

Table 1 shows the results of a few incubator experiments conducted with *A. avenæ* and *A. pomi*. The various columns are self explanatory; the second from the right gives the total percentage of hatch of all the eggs after all hatched or shriveled, and the column to the extreme right gives the number of days required to shrivel and kill all the eggs. The percentage of hatch might have varied a little in the different experiments if a larger number of eggs had been used; however, the results unquestionably show that different percentages of moisture have a decided influence on the emergence of the nymph. The largest percentage of hatch occurred in saturated air, and practically no hatch in dry air. This decided influence of moisture probably accounts for the low percentage of hatch recorded for *A. pomi* by Gillette (6), in Colorado, where the relative humidity of the climate is much less than at New Brunswick, N. J.

The rate of shrivel of the eggs in the different percentages of moisture in all the experiments is also significant. This is particularly true in the experiments with the eggs of *A. pomi* (exp. 109-112) which never hatched. Eggs of *A. pomi* will not hatch when brought into greenhouse or laboratory temperatures unless it is near the normal out-of-door hatching period, not over 20 to 30 days before hatching.

In experiments 109-112 dry air completely shriveled the eggs in 7 days while saturated air required 24 days. In other words, in these experiments and also in all others pertaining to moisture, the rate of shrivel shows that the water evaporated from eggs in dry air, or 22 per cent humidity, in one-half to one-third the time required for eggs under 63 per cent moisture, or complete saturation. Comparing the rate of shrivel of the eggs in experiments 109-112 started on March 14 with those of the same species (exp. 105-108) started on April 6, the eggs of the latter shriveled more rapidly. This increase in the rate of shrivel is closely correlated with the greater percentage of eggs showing split outer coverings near the hatching period.

The above experiments show that the outer, semi-transparent brittle layer of the egg is permeable to water and cannot conserve the moisture content of the embryo when exposed to adverse dry conditions, but it does conserve a sufficient quantity of moisture under normal out-of-door conditions, so that 25 per cent or more of the eggs hatch. These experiments also indicate that the eggs are most susceptible to drought just previous to the hatching period. This is apparently due to the fact that almost all the normal eggs preparing to hatch show a split outer covering and this splitting of the outer shell exposes the permeable pigmented layer to adverse conditions, thus increasing the rate of evaporation.

A simple experiment was conducted to determine the relative permeability of the pigmented layer and the outer semi-transparent layer. The outer layer *t* was carefully removed from 15 normal eggs of *A. avenæ* on April 5, and the plump-skinned eggs were transferred to a Syracuse watch glass with a piece of blotting paper on the bottom. Fifteen normal plump eggs also were placed in the same watch glass and a piece of moist blotting paper was added, but this did not come in contact with any of the eggs. A similar watch glass was used as a cover.

TABLE 2

INFLUENCE OF MOISTURE ON SKINNED EGGS AND NORMAL EGGS

Condition of eggs	90 minutes	4 hours	24 hours	48 hours*	8 days
15 skinned eggs	12 slightly shriveled; 3 normal	15 shriveled; 8 completely collapsed	15 completely collapsed	15 completely collapsed	15 completely collapsed
15 normal eggs	15 normal	15 normal	13 normal; 2 shriveled	11 normal; 2 shriveled; 2 hatched	9 shriveled; 6 hatched

*Observations made between 48 hours and 8 days omitted from table.

The results from these experiments are conclusive; the pigmented or second layer about the egg is very permeable when compared with the outer semi-transparent layer, for the water content of all the skinned eggs was completely evaporated in 24 hours. The normal eggs were much more resistant, for in 24 hours only two eggs showed a slight indication of shriveling, none of the skinned eggs hatched, while 6 of the 15 normal eggs hatched in 4 days. In brief, this experiment shows that the brittle outer layer acts as a preventive agent against water evaporation under normal conditions, while the inner pigmented layer does not perform this function to any great extent.

Under out-of-door conditions the percentage of hatch of the eggs of *A. avenæ* has been observed for two seasons. In 1917

approximately 50 per cent of the eggs of this species hatched, while in 1918 about 30 per cent hatched, a difference of 20 per cent. Among selected eggs used in the checks for experiments conducted out-of-doors from February 19 to April 1, an average of 56 per cent of the eggs hatched in 1917, while 44 per cent hatched in 1918, a difference of 12 per cent. The above difference in the percentages of hatch for the two seasons is believed to be due to the decided difference in the weather. In 1917 we experienced many wet and cold days throughout the last two weeks in February and almost all of March. The last two weeks of March in 1917 were particularly wet (March 15-31). In 1918 the later part of February resembled the same period in 1917, but the entire month of March was comparatively dry, especially the last two weeks, and this weather was very conducive to high evaporation. Unfortunately, only occasional records were made of the humidity during these two years, but in 1918 a number of days in the last weeks of March showed 40 per cent of moisture at mid-day. Table 3 shows the rainfall for the two seasons covering six weeks, February 15 to March 31. A comparison shows immediately a decided difference in the amount of rainfall, especially for the last weeks in March, and these weeks are the most important for at this time the greatest number of eggs have their outer coverings split, thus exposing the permeable pigmented layer to evaporating factors such as low humidity, high temperature and wind velocity. During March 15 to March 31, 1917, 1.59 inches of rain fell, 8 days out of 19 gave over 0.01 inch of rain and 9 days out of 15 were cloudy or partly so, while in 1918, 0.22 inch of rain fell, and only 3 days out of 15 were partly cloudy. During March 15-31, 1917, there was a mean maximum of 53°F., and a mean minimum of 32.1°F., while in 1918 the mean maximum was 59.3°F. and the mean minimum 33.6°F. thus in 1918 there was an increase of 6.3°F. in the mean maximum and 1.5°F. in the mean minimum. This difference in temperature along with the decided difference in rainfall and cloudy days means that the humidity was probably greater in 1917 than in 1918. All the above characteristics of the weather for March, particularly March 15-31, show that the evaporation of moisture from the split eggs would be much greater in 1918 than in 1917, and this being the case the percentage of hatch would be lower for 1918. This is actually true, as shown above among eggs collected from various orchards and also among selected eggs used as checks in various experiments for the two seasons.

TABLE 3

PRECIPITATION FOR FEBRUARY 15 TO MARCH 31, 1917 AND 1918

February	Precipitation		March	Precipitation		March	Precipitation	
	1917	1918		1917	1918		1917	1918
	inches	inches		Inches	Inches		Inches	Inches
15		0.02	1		0.03	17	0.49	
16			2	0.23		18	T	
17			3	T		19		
18			4	1.18		20		
19		0.43	5	0.09	0.18	21	0.17	
20	0.11	0.92	6		0.04	22		
21			7		0.19	23		
22	0.29	0.05	8	0.50		24	0.42	0.22
23	T		9	T	0.02	25		
24	0.37		10		0.20	26		
25			11	0.09		27	0.37	T
26		0.98	12		0.02	28	0.14	T
27	0.03		13			29	T	
28	0.35		14	0.18	0.84	30		
			15	0.01	0.03	31	T	
			16					
Total	1.15	2.40		2.28	1.15		1.59	0.22

T—trace

One may question the influence of humidity on the percentage of hatch for the past season and claim that the smaller percentage was due to the decidedly cold and severe winter (1917-18). The influence of cold weather is questioned by the author for two reasons. In the first place from 50 to 55 per cent of the eggs out-of-doors split their outer coverings, thus giving conclusive evidence that they were alive and preparing to hatch. In the second place, on February 26, eggs were collected from John Barclay's orchard and brought into the laboratory (70°F.) and placed in a chamber which continuously registered 90 per cent moisture or even greater. Of these eggs 50.5 per cent split their outer shells and 43.5 per cent hatched; while a similar lot of eggs (500) from the same collection were kept out-of-doors where the humidity on some of the days (March 15-31, 1918) registered 40 per cent or below at mid-day, and showed only a 29 per cent hatch, or a difference of 14.5 per cent when compared with the indoor experiment. This difference in percentage of hatch is accounted for by the decided difference in the percentage of moisture.

The foregoing experiment, the important observations on the morphological changes which take place in the egg before the nymphs emerge, the records made on the percentage of hatch of *A. avenæ* during the decidedly different seasons of 1917 and 1918 (March 15-31), the results obtained from the experiments conducted with controlled moistures in the incubators during 1917, and the significant facts observed with skinned and normal eggs under laboratory conditions, make us conclude that the percentage of hatch among eggs of apple aphides is influenced to a considerable

extent by weather conditions, especially during the few weeks previous to the emergence of the nymph. In brief, the existence of high evaporating factors during the dormant season, especially after the outer egg shell has split, kills a large number of eggs which would normally complete the process of hatching in weather with low evaporating factors. In order that the above relationship between the percentage of hatch and the condition of the weather may be proved and its significance ascertained, especially in regions where the average humidity is low, it is suggested that observations be made in various states, on the percentage of hatch for the various species concerned.

Temperature

Temperature has a marked and peculiar influence upon the hatching of the eggs of all three species. Some of these influences have been mentioned. In 1917 eggs of *A. pomi* and *A. sorbi* were brought into the greenhouse during February and the early part of March (up to March 14) and these failed to hatch, while eggs of *A. avenæ* brought into the greenhouse at the same time showed a normal percentage of hatch. During 1917-18 eggs of *A. avenæ* collected in November and placed in the greenhouse showed a 10 per cent hatch during the first week in February, while eggs collected on February 26, and put in a moist chamber in the laboratory showed a 43.5 per cent hatch. This difference in the percentage of hatch (also true for other experiments during December and January) may be due to the fact that an exposure to low temperatures is beneficial for the majority of the eggs of *A. avenæ*. As noted before, the greenhouse was closed early in February during 1918 and the transfer of the eggs to a moist tin compartment in the laboratory may have had some influence on the percentage of hatch. In order to be sure of the above statement concerning the eggs of *A. avenæ* it will be necessary to repeat these experiments. Eggs of *A. pomi* and *A. sorbi* will hatch under laboratory or greenhouse conditions provided they are not brought into the laboratory or greenhouse over 20 to 30 days before they normally hatch out-of-doors. The above peculiarity in the hatching of the eggs has also been noted by Baker and Turner (2) and other investigators. For some unknown reason, long exposure to low temperatures is essential for the normal development of the embryo of *A. pomi* and *A. sorbi,* and it may be beneficial for the majority of the eggs of *A. avenæ*.

Temperature also influences the egg when it is preparing to hatch. It was repeatedly noted that the percentage of eggs with a split outer covering would always show a decided increase during or following a day or two of exceptionally warm weather. This was particularly true during the latter part of February and the

early part of March. When the nymphs were emerging (March 21 to April 5) the rate of emergence was influenced by the temperature. On warm days the greatest number came out. The eggs of *A. avenæ* started to hatch on March 21 during the past season, while in 1917 the first nymphs were seen on March 28. This difference is undoubtedly due to the difference in the temperature mentioned above for the last two weeks in March for 1917 and 1918.

After the nymphs have emerged they are somewhat susceptible to low temperatures. At least it was noted that on April 6, 1918, in many unsprayed orchards, especially around Riverton, N. J., the nymphs of *A. avenæ* were very abundant, each bud on some trees showing ten or more. On April 9-11 a severe drop in temperature took place (enough to frost the edges of the small protruding leaves), and a heavy snow and sleet storm accompanied the change in temperature. On April 18 these trees were examined and the heavy infestation was reduced below the danger point; in fact, in some orchards adjacent to the Delaware river no aphides could be found. The results of spraying experiments in this section of the state and likewise in other portions during the past season were not as striking as in 1917, on account of the storm. Possibly the sleet and snow were as beneficial in killing the nymphs as the cold weather.

Contact Insecticides and Other Chemicals

The foregoing morphological and ecological study of the eggs of apple plant lice shows conclusively that they are not as firm and impenetrable as some entomologists would have us believe, and furthermore they are especially susceptible to differences in moisture and temperature a few weeks previous to the emergence of the nymph and also as the nymph emerges. These facts naturally lead us to assume that certain common contact insecticides and various chemicals applied just before the nymphs emerge should affect the eggs and cut down the percentage of hatch. This is unquestionably the case, for a number of investigators using lime-sulfur at winter strength, crude oil emulsion and other sprays have met with success in killing the aphid in the egg stage when the spray was applied late in the season, in most cases just as the buds were bursting. A brief review of these investigations has been made by P. R. Jones (12). Dr. T. J. Headlee's experiments with lime-sulfur in 1916 at John Barclay's orchard also show that the rosy aphis, *A. sorbi,* is killed in the egg stage.

The exact physical and chemical effect of the various sprays on the egg has never been explained and, so far as is known, is still more or less a mystery. In order to understand the chemical reaction of various substances on the egg-shell, it is necessary to

have some knowledge of the chemical nature of the layers about the egg. A few qualitative tests have been conducted with this point in view, but as yet nothing definite has been determined. From a physical standpoint the effect of certain substances has been observed and these will be discussed briefly.

In order to control the aphid in the egg stage the material used must prevent the nymph from hatching or it may be of such a nature as to kill the nymph as it hatches. The preventive may act in several ways. Any substance which will harden the outer semi-transparent shell and thus makes it impossible for the nymph to emerge would be satisfactory, or the material used could have the opposite effect, that is, soften or dissolve the outer layer and thus expose the inner, pigmented layer to evaporating factors such as wind, heat or low humidity. Furthermore, many substances are splendid dessicating agents and any material possessing this quality might be able to extract the water content of the ovum or embryo and thus prevent further development. Again, the use of any toxic substance which will penetrate the egg coverings and attack the living embryo would naturally be a control measure. Another possible means of control would be the discovery of some chemical which will loosen the egg from the twig and cause it to fall to the ground.

Dormant lime-sulfur apparently hardens the outer covering, at least it was noted that a number of treated eggs did not completely collapse and in many cases the outer layer retained its normal shape while the black pigmented layer and the contents of the embryo within were completely shriveled. Such eggs are easily recognized in that they are lighter in color because of the air space within. Besides this hardening effect, lime-sulfur seems to act as a dessicating agent and it may also actually penetrate all the layers and serve as a toxic substance on the embryo.

So far as could be seen with a microscope, no decided visible effect was evident in eggs treated with other common contact insecticides such as nicotine, soap solutions and miscible oils. In some cases where eggs were treated with miscible oil, particularly oils which possess some crude carbolic derivatives, they appeared to be more glossy. So far as is known, the above substances probably act as toxic agents which kill by penetrating the layers of the egg and attacking the embryo.

A weak solution of crude carbolic acid will soften and apparently disintegrate the outer shell of the aphid egg. In several experiments the eggs of *A. avenæ* and *A. pomi* were sprayed with a 1 per cent and a 2 per cent solution of crude carbolic acid, and with varying strengths of cresol (U. S. P.) plus enough laundry soap to break the surface tension. In a few minutes after treatment

TABLE 4

RESULTS OF SPRAYING EXPERIMENTS WITH EGGS OF A. AVENAE AND A. POMI (A. sorbi) FOR 1917

Number of Exp.	Spray	Species	Date of Spray	Total Eggs	Total Hatch	Percentage Hatched
G- 1	Check	*A. avenae*	Feb. 27	108	91	84.2
G- 2	Check	*A. avenae*	Mar. 7	49	16	32.6
G- 3	Check	*A. avenae*	Mar. 10	70	44	62.8
G- 4	Check	*A. avenae*	Mar. 16	58	37	63.8
G- 5	Check	*A. avenae*	Mar. 27	50	34	68.0
O- 6	Check	*A. avenae*	Mar. 12	68	20	29.5
O- 7	Check	*A. avenae*	Mar. 30	54	32	59.2
O- 8	Check	*A. avenae*	Apr. 3	55	22	40.0
O- 9	Check	*A. pomi*	Apr. 6	221	110	49.7
O-11	Check	*A. pomi*	Apr. 7	104	39	37.5
O-10	Check	*A. pomi*	Apr. 16	104	49	47.2
G-12	Lime-sulfur, 1-8	*A. avenae*	Feb. 27	102	4	3.9
G-13	Lime-sulfur, 1-2	*A. avenae*	Mar. 7	42	0	0.0
G-14	Lime-sulfur, 1-4	*A. avenae*	Mar. 7	52	1	1.9
G-15	Lime-sulfur, 1-8	*A. avenae*	Mar. 7	43	0	0.0
G-16	Lime-sulfur, 1-8, plus pyridine solution, 1-100	*A. avenae*	Mar. 7	42	0	0.0
G-17	Lime-sulfur, 1-8, plus sodium chloride, 1 gm.-5 cc.	*A. avenae*	Mar. 7	45	0	0.0
O-18	Lime-sulfur, 1-8	*A. avenae*	Mar. 12	53	1	1.8
O-19	Lime-sulfur, 1-4	*A. avenae*	Mar. 12	50	0	0.0
O-20	Lime-sulfur, 1-8, plus sodium chloride, 1 gm.-5 cc.	*A. avenae*	Mar. 12	54	0	0.0
O-21	Lime-sulfur, 1-4, plus sodium chloride, 1 gm.-5 cc.	*A. avenae*	Mar. 12	50	1	2.0
O-22	Lime-sulfur, 1-8	*A. avenae*	Mar. 30	50	1	2.0
O-23	Lime-sulfur, 1-8	*A. pomi*	Apr. 6	219	16	7.3
O-24	Lime-sulfur, 1-8	*A. pomi*	Apr. 16	107	5	4.6
O-25	Lime-sulfur, 1-8, plus "Black-leaf 40", 1-500	*A. pomi*	Apr. 16	103	1	0.9
G-26	"Mechling's Scale-Oil", 1-9.5	*A. avenae*	Mar. 10	49	4	8.1
G-27	"Mechling's Scale-Oil", 1-19	*A. avenae*	Mar. 10	47	3	6.3
G-28	"Mechling's Scale-Oil", 1-19, plus crude carbolic, 2%	*A. avenae*	Mar. 10	52	0	0.0
O-29	"Mechling's Scale-Oil", 1-19	*A. avenae*	Mar. 30	49	4	8.1
O-30	"Mechling's Scale-Oil", 1-19, plus crude carbolic, 2%	*A. avenae*	Mar. 30	53	0	0.0
O-31	"Mechling's Scale-Oil", 1-19	*A. pomi*	Apr. 7	105	9	8.5
O-32	"Mechling's Scale-Oil", 1-19, plus fish-oil soap 1 gm.-200 cc.	*A. pomi*	Apr. 7	102	10	9.8
O-33	"Mechling's Scale-Oil", 1-19, plus crude carbolic, 2%	*A. pomi*	Apr. 7	175	0	0.0
G-34	"Scalecide", 1-15	*A. avenae*	Mar. 27	52	12	23.0
G-35	"Scalecide", 1-15, plus crude carbolic, 2%	*A. avenae*	Mar. 27	51	2	3.9

O-36	"Scalecide", 1-15	*A. avenae*	Mar. 30	52	18	34.6
O-37	"Scalecide", 1-15, plus crude carbolic, 2%	*A. avenae*	Mar. 30	51	0	0.0
O-38	"Scalecide", 1-15	*A. pomi*	Apr. 6	207	16	22.8
O-39	"Scalecide", 1-15, plus crude carbolic, 2%	*A. pomi*	Apr. 6	192	2	1.0
O-40	"Scalecide", 1-15	*A. pomi*	Apr. 16	110	35	31.7
O-41	Laundry soap, 1 gm.-200 cc.	*A. avenae*	Apr. 3	51	20	39.2
O-42	L. soap, 1 gm.-200 cc., plus "Black-leaf 40", 1-100	*A. avenae*	Apr. 3	50	8	16.0
O-43	L. soap, 1 gm.-200 cc., plus "Black-leaf 40", 1-250	*A. avenae*	Apr. 3	51	6	11.7
O-44	L. soap, 1 gm.-200 cc., plus "Black-leaf 40", 1-500	*A. avenae*	Apr. 3	49	11	22.4
G-45	Laundry soap, 1 gm.-200 cc.	*A. avenae*	Mar. 10	56	22	39.2
G-46	L. soap, 1 gm.-200 cc., plus crude carbolic, 2%	*A. avenae*	Mar. 10	41	1	2.4
G-47	L. soap, 1 gm.-200 cc., plus crude carbolic, 5%	*A. avenae*	Mar. 10	41	0	0.0
G-48	L. soap, 1 gm.-200 cc., plus crude carbolic, 0.5%	*A. avenae*	Mar. 27	54	19	35.1
G-49	L. soap, 1 gm.-200 cc., plus crude carbolic, 1%	*A. avenae*	Mar. 27	50	3	6.0
G-50	L. soap, 1 gm.-200 cc., plus crude carbolic, 2%	*A. avenae*	Mar. 27	49	0	0.0
G-51	L. soap, 1 gm.-200 cc., plus crude carbolic, 5%	*A. avenae*	Mar. 27	50	0	0.0
O-52	L. soap, 1 gm.-200 cc., plus crude carbolic, 2%	*A. avenae*	Mar. 12	45	1	2.2
O-53	Laundry soap, 1 gm.-200 cc.	*A. avenae*	Mar. 30	50	22	44.0
O-54	L. soap, 1 gm.-200 cc. plus crude carbolic, 0.5%	*A. avenae*	Mar. 30	51	8	15.3
O-55	L. soap, 1 gm.-200 cc. plus crude carbolic, 1%	*A. avenae*	Mar. 30	49	7	14.3
O-56	L. soap, 1 gm.-200 cc. plus crude carbolic, 2%	*A. avenae*	Mar. 30	50	1	1.6
O-57	L. soap, 1 gm.-200 cc. plus crude carbolic, 5%	*A. avenae*	Mar. 30	51	0	0.0
O-58	L. soap, 1 gm.-200 cc. plus crude carbolic, 10%	*A. avenae*	Mar. 30	50	0	0.0
O-59	Laundry soap, 1 gm.-200 cc.	*A. pomi*	Apr. 6	200	68	34.0
O-60	L. soap, 1 gm.-200 cc. plus crude carbolic, 2%	*A. pomi*	Apr. 6	50	7	1.4
G-61	Fish-oil soap (solid), 1 gm.-200 cc., plus crude carbolic 2%	*A. avenae*	Feb. 27	53	2	3.7
G-62	Fish-oil soap (solid), 1 gm.-200 cc., plus crude carbolic 5%	*A. avenae*	Feb. 27	47	0	0.0
G-63	Fish-oil soap (solid), 1 gm.-10 cc.	*A. avenae*	Mar. 27	51	2	3.9
O-64	Fish-oil soap (solid), 1 gm.-200 cc., plus crude carbolic 2%	*A. avenae*	Mar. 12	51	1	1.9
O-65	Fish-oil soap (solid), 1 gm.-25 cc.	*A. pomi*	Apr. 7	100	2	2.0
O-66	Fish-oil soap (solid), 1 gm.-50 cc.	*A. pomi*	Apr. 7	100	5	5.0
O-67	Fish-oil soap (solid), 1 gm.-100 cc.	*A. pomi*	Apr. 7	102	2	2.0
O-68	Fish-oil soap (solid), 1 gm.-25 cc., plus crude carbolic 1%	*A. pomi*	Apr. 7	105	1	0.9
O-69	Fish-oil soap (solid), 1 gm.-50 cc., plus crude carbolic 1%	*A. pomi*	Apr. 7	110	0	0.0
O-70	Fish-oil soap (solid), 1 gm.-100 cc., plus crude carbolic 1%	*A. pomi*	Apr. 7	99	0	0.0
O-71	Fish-oil soap (solid), 1 gm.-200 cc., plus crude carbolic 2%	*A. pomi*	Apr. 16	100	2	2.0
G-72	Sodium hydroxide,2 gm.-98 cc.	*A. avenae*	Mar. 10	31	3	9.6
O-73	Sodium hydroxide, 2 gm.-98 cc.	*A. avenae*	Mar. 12	54	1	1.8
O-74	Sodium chloride, 1 gm.-5 cc.	*A. avenae*	Mar. 13	52	11	21.1
G-75	Sodium chloride, 1 gm.-5 cc.	*A. avenae*	Mar. 16	50	21	42.4
G-76	L. soap, 1 gm.-200 cc., plus sodium sulfocarbonate, 1-19	*A. avenae*	Mar. 10	39	6	15.3
G-77	L. soap, 1 gm.-200 cc. plus sodium sulfocarbonate, 1-9	*A. avenae*	Mar. 10	38	1	2.6
O-78	L. soap, 1 gm.-200 cc., plus pyridine solution, 2%	*A. avenae*	Mar. 10	45	26	57.7
O-79	L soap, 1 gal. 200 cc , plus pyridine solution, 1% plus crude carbolic 1%.	*A. avenae*	Mar. 10	45	6	13.3

G—Greenhouse and O—Out-of-door Experiments.

the brittle outer layer, split or whole, was softened and wrinkled (plate 1, fig. 13) and could be easily removed. Furthermore, it was noted that in all experiments where crude carbolic acid was used as a spray, especially in strengths greater than 1 per cent, the eggs had an unusually bright shiny appearance after the spray had dried. This glossy appearance indicates that the semi- transparent outer layer has undergone some sort of a change. It was also observed that many eggs with split outer coverings treated with crude carbolic acid and cresols shriveled along the meso-dorsal line (plate 1, fig. 14). This type of shrivel which also takes place to some extent with other treatments indicates that the pigmented layer of an egg showing a split outer shell is particularly susceptible to various chemicals. Furthermore, treated eggs with a whole outer covering frequently shriveled in a like manner. This indicates that the outer shell is weakest along the meso-dorsal line and any foreign material which can soften or disintegrate the outer layer would naturally penetrate this portion of the egg first and cause it to show its early stage of shriveling along the least resistant portion.

A number of other chemicals were tried and their effect noted, but their mode of attack has not been observed with sufficient care to warrant a statement at this time. Possibly it would be worth while to call attention to the fact that sodium hydroxide seems to react upon the glutinous layer in such a manner as to loosen the egg from the tree and cause it to fall to the ground. At least a large number of eggs were lost in all the experiments with sodium hydroxide.

A large number of experiments were conducted with various common sprays and other chemicals during March and April, 1917, and the results of the more important of these are recorded in table 4. The predominant species of eggs used in the various experiments is indicated in the table. In the experiments with *A. avenæ* a few eggs of *A. sorbi* were present, but, so far as is known, these never exceeded 15 per cent of the total number, while in the experiments with *A. pomi* the eggs of *A. sorbi* ran close to 30 per cent (at least a number of counts of newly-hatched stem mothers gave this approximate percentage). This percentage of the eggs of *A. sorbi* in the experiments shows that the eggs of this species resemble those of *A. avenæ* and *A. pomi* in their response to various stimuli; however, there is apparently some difference in the susceptibility of the different species. At least there is good indication of this if one compares the percentages of hatch among the different species under similar treatments. *A. avenæ* is probably somewhat more susceptible than either *A. pomi* or *A. sorbi*. Another point of interest in respect to susceptibility is the fact that all eggs of

one species are not alike; some are less resistant than others, consequently some are killed by weaker strengths of insecticides. This is well illustrated in all experiments, particularly in the experiments where the percentage of hatch runs between 10 and 25 per cent among treated eggs.

The percentages of hatch or kill in all the spraying experiments in the greenhouse or out-of-doors at the laboratory for the two seasons are figured on the basis of considering the number of eggs present at the time the final observations were made. In a former paper (19) the percentage of hatch was figured on the basis of considering the percentage of hatch in respective checks for each set of experiments as 100 per cent, and then the number of eggs hatched in the various experiments compared with the check. Experience has shown that this method is subject to considerable variation due to the variation in the percentage of hatched eggs in the checks; consequently, this method was abandoned for the above mentioned form. In all the tables the percentage of hatched eggs is given for each experiment and one may obtain the percentage of killed or dead eggs by subtracting the percentage of hatched eggs from 100 per cent. The results given in table 4 will be considered in the various discussions on the different insecticides and chemicals.

Upon completing the investigations on the aphid eggs for the season of 1916-17, it was observed that the susceptibility of the eggs to various insecticides and different percentages of humidity seemed to be greatest just prior to the emergence of the nymph. With this observation in mind, a large series of spraying experiments, starting with November 30, 1917 and continuing until April 1, 1918, were conducted out-of-doors at the laboratory for the purpose of determining the relative susceptibility of the eggs throughout the dormant season.

Diagram 1, by an intersection of plotted lines with perpendicular lines (representing dates of application) shows the results of the more important experiments conducted with the eggs of *A. avenæ*. The dates at the top of the chart indicate the time of application of the various substances used. Other applications were made throughout the month of December and January, but the results of the spraying experiments for December 15 are typical of all these. The points of intersection of the various types of plotted lines with the perpendicular date lines indicate the percentage of hatch if one examines the column of figures to the left, and the percentage of dead eggs if one examines the column of figures to the right. Each treatment or substance used as a spray is given a definite letter, the explanation of which may be found at the bottom of the chart. The chart also shows at the top the source or orchard where the eggs were collected and on the bottom

line the percentage of eggs showing a split outer shell at the time the treatment was given. The average percentage of hatch, 48 per cent, or percentage of dead eggs, 52 per cent, for the untreated eggs, or checks is represented by a straight line.

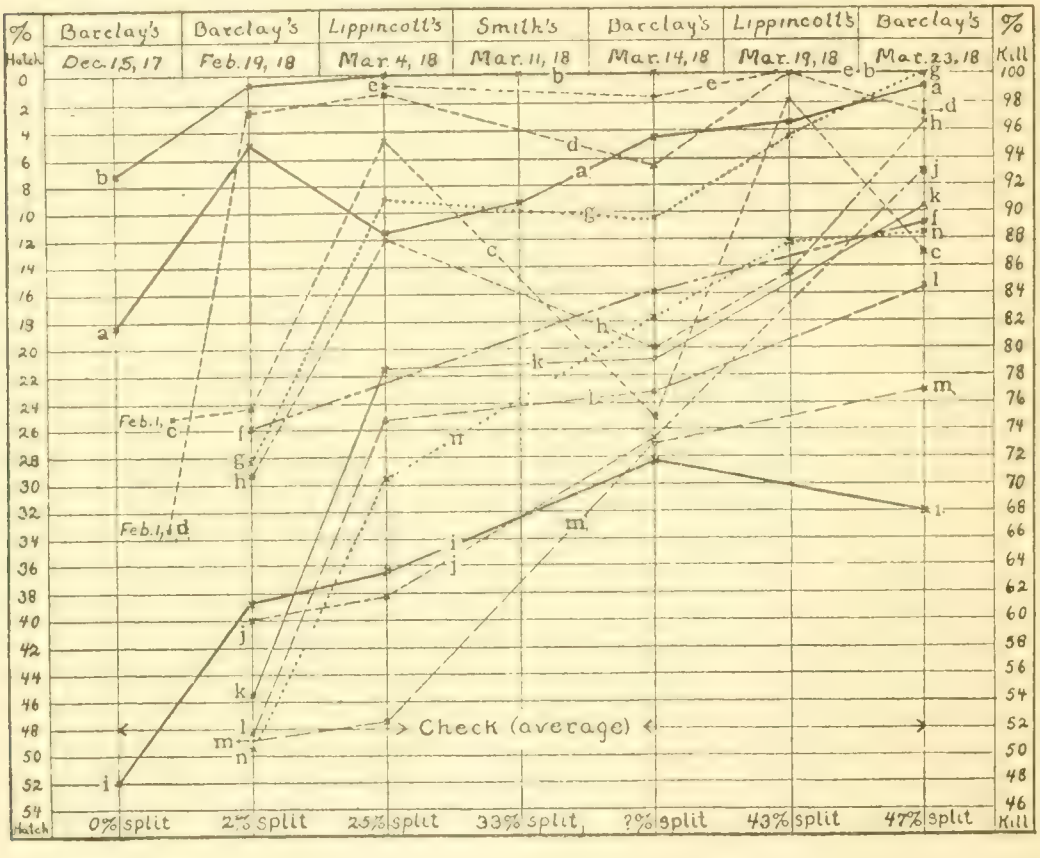

Diagram 1. Chart showing progressive decrease in the percentage of hatched eggs or increase in the percentage of dead eggs with the various sprays when they are applied nearer the time when the nymphs emerge (Emergence March 21 to April 5).

a—Lime-sulfur, 1-9

b—Lime-sulfur, 1-9 plus nicotine, 1-500

c—"Scalecide," 1-15

d—"Scalecide," 1-40 plus cresol, 1%

e—"Scalecide," 1-15 plus crude carbolic, 1%

f—F. o. soap, 1 gm.-50 c. c. plus phenol, 1%

g—F. o. soap, 1 gm.-50 c. c. plus nicotine, 1-500

h—F. o. soap, 1 gm.-50 c. c. plus crude carbolic, 1%

i—Laundry soap, 1 gm.-200 c. c. plus cresol, 1%

j—F. o. soap, 1 gm.-100 c. c. plus crude carbolic, 0.5%

k—F. o. soap, 1 gm.-100 c. c. plus cresol, 1%

l—Fish oil soap (solid), 1 gm.-50 c. c.

m—Resin fish oil soap, 1 gm-50 c. c.

n—Nicotine resinate, 1-500

Several interesting and important points are brought out in this chart, but the most striking and significant one is the fact that almost all the substances used show a gradual progressive decrease in the number of eggs hatched (or vice versa, a progressive increase in the number of dead eggs), when the spray is applied nearer the

time when the nymphs emerge. In all the experiments, no matter what substance was used, the percentage of hatched eggs was less when the substance was applied on March 23 than when applied in December, January, February or March 4.

Briefly stated, the greatest number of eggs are killed in all the experiments when the spray is applied just prior to the emergence of the nymph. This gradual increase in susceptibility is dependent upon the increase in the percentage of eggs showing split outer shells. On the basis of the facts shown in the chart and from foregoing observations on the morphology and behavior of the egg previous to the emergence of the nymph, we may conclude that the greater the percentage of eggs possessing split outer shells the greater will be the percentage of dead eggs when contact insecticides are used.

LIME-SULFUR

A large number of experiments were conducted on the eggs of all the species in the greenhouse, out-of-doors at the laboratory, and in various orchards during the past two seasons, using different strengths of lime-sulfur and lime-sulfur combined with nicotine. During February, March and April, 1917, experiments G-12 to G-17 and 0-18 to 0-25 (table 4), were performed in the greenhouse (G) and out-of-doors (0) with the eggs of all three species, and the results show a very decided reduction in the percentage of hatched eggs and in some instances a complete kill. Eggs of *A. avenæ* sprayed with lime-sulfur 1-8 and kept under greenhouse conditions or out-of-doors at the laboratory showed a very small percentage of hatch or a complete kill (3.9 to 0.0. per cent hatch). Eggs of *A. pomi* receiving similar treatment showed a 2.0 to 7.3 per cent hatch. A comparison of these percentages among the two predominant species in the respective experiments shows that the eggs of *A. avenæ* are more susceptible to lime-sulfur than *A. pomi*. Lime-sulfur 1-6 and greater strengths gave better control than 1-8 or 1-9.

In a few experiments lime-sulfur was combined with sodium chloride, a pyridine solution and nicotine sulfate. The results of the experiments with the first two chemicals mentioned are discussed under other chemicals. During 1917 one experiment (exp. 0-25, table 4) was conducted out-of-doors at the laboratory with the eggs of *A. pomi* where nicotine, "Black-leaf-40", was used at the rate of 1-500 and the percentage of hatch was 0.9 per cent, while another experiment with lime-sulfur, 1-8 (exp. 0.24, table 4) gave a 4.6 per cent hatch. These results indicated the possibility of obtaining a more perfect control when a combination spray was used, consequently a large number of experiments were conducted

TABLE 5

EXPERIMENTS WITH LIME-SULFUR AND LIME-SULFUR COMBINED WITH NICOTINE ("Black-leaf 40") ON SELECTED EGGS OF A. AVENAE.

Spray	Lime-sulfur, 1-9		Lime-sulfur, 1-6		Lime-sulfur, 1-9 "Black-leaf 40", 1-250		Lime-sulfur, 1-9 "Black-leaf 40", 1-500		Lime-sulfur, 1-9 "Black-leaf 40", 1-1,000		Check	
Date Sprayed and Source of Eggs	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched
Dec. 15, 1917 Smith's	72 h 186	38.6			2 h 70	2.8	28 h 140	16.6	4 h 81	4.9	134 h 215	62.2
Dec. 15, 1917 Barclay's	38 h 208	38	18.2		4 h 94	4.2	11 h 154	7.1	14 h 95	14.7	116 h 246	47.1
Feb. 19, 1918 Barclay's	8 h 164	4.8			0 h 99	0.0	1 h 172	0.6	0 h 108	0.0	128 h 278	46.0
Mar. 4, 1918 Lippincott's	12 h 99	12.1	0 h 109	0.0			0 h 114	0.0	0 h 103	0.0	45 h 135	33.3
Mar. 11, 1918 Smith's	8 h 85	9.4	4 h 89	4.4			0 h 103	0.0			62 h 130	47.6
Mar. 14, 1918 Barclay's	5 h 110	4.5	0 h 110	0.0			0 h 109	0.0	0 h 105	0.0	97 h 212	45.7
Mar. 19, 1918 Lippincott's	4 h 104	3.8	1 h 84	1.1			0 h 112	0.0	0 h 95	0.0	89 h 201	44.2
Mar. 22, 1918 Barclay's	1 h 104	0.9	0 h 89	0.0			0 h 115	0.0	0 h 98	0.0	34 h 104	32.6

h = hatched eggs.

with varying strengths of lime-sulfur alone and in combination with nicotine during the past season (1917-18). The results of these experiments conducted on the eggs of *A. avenæ* out-of-doors at the laboratory are shown in condensed form in table 5. Some of the series of experiments are also shown in diagram 1 (p. 27).

Table 5 shows in the left column the date of application of the spray and the source of the eggs for each experiment in the various series, while the top line gives the treatment in each series. The table also shows for each experiment the number of eggs hatched *h*, the total number of eggs in the experiment and the percentage of hatch. If one chooses to express the effectiveness of the different sprays in terms of the percentage of kill, subtract the percentage of hatch from 100 per cent. The following example explains what is shown for each experiment. The experiment in the upper left corner shows that the eggs were collected from Smith's orchard and sprayed on December 15 with lime-sulfur 1-9. After they had completed hatching, 72 had hatched out of 186, or 38.6 per cent. Subtracting 38.6 per cent from 100 per cent gives 61.4 per cent killed. This experiment alone shows the ineffectiveness of applying lime-sulfur to eggs during the month of December. The same thing also holds for the month of November, January and the first part of February. The results of the various series of experiments for the above months are not shown in the table, since they are similar to those obtained in December.

The table summarizes the results of the experiments conducted out-of-doors with lime-sulfur and nicotine, consequently it will not be necessary to give a detailed discussion of the various interesting experiments. An examination of the table shows off-hand, in all the series of experiments where the same material was used, that the greatest reduction in the percentage of hatch always occurred where the treatments were applied near the time of the emergence of the nymph. These observations, then, fully agree with a former statement—the greater the percentage of eggs showing a split outer shell, the greater the percentage of kill. Lime-sulfur 1-9 during the past season did not kill 100 per cent of the eggs in any one experiment; however, it did kill 99.1 per cent on March 22; but lime-sulfur 1-6 was more effective, and in two experiments during March killed 100 per cent of the eggs. Lime-sulfur 1-9 combined with nicotine 1-500 or 1-1000 killed 100 per cent of the eggs when applied during the month of March. According to these experiments nicotine at the rate of 1-1000 when combined with lime-sulfur 1-9 is just as effective in killing the eggs as nicotine at the rate of 1-500. This may be true for eggs of *A. avenæ*, but when one wishes to kill 100 per cent of the nymphs that have hatched, the nicotine should be used at the rate of 1-500, as shown by Dr. T. J. Headlee in experiments conducted on apple plant lice during 1916.

Orchard Experiments

During the past two seasons the author has made detailed records on results obtained in various orchards throughout the state, and we are indebted to various owners and managers of orchards for cooperation in this work. In 1917 careful observations were made at Mr. John H. Barclay's orchard. Mr. Barclay delayed the spraying with dormant lime-sulfur 1-9 until the buds started to swell, in order that the spray might be applied near the

TABLE 6

EFFECT OF DORMANT LIME-SULFUR 1-9 ON EGGS OF A. AVENAE DURING THE HATCHING PERIOD, AT JOHN H. BARCLAY'S ORCHARD

(1917)

No.	Date Sprayed Collected	Date Observed	Total Eggs	Number and Percentage of Eggs Hatched	Number and Percentage of Normal Eggs	Number and Percentage of Eggs Shriveled
1	Sprayed April 4 and	April 4	504	116 23.2%	184 36.3%	204 40.5%
	Collected April 4	April 11	504	119 23.5%	45 8.9%	304 67.4%
2	Sprayed April 2 and Collected April 14	April 16	564	118 20.9%	11 2%	435 77%
3	Check: Collected	April 3	360	103 28.3%	116 33%	141 39%
	March 31	April 14	360	118 32%	4 1%	238 66.1%
4	Check. Collected	April 5	466	275 59%	56 14%	135 27%
	March 24	April 14	466	299 64.1%	10 2.1%	157 33.7%

hatching period of *A. sorbi.* Dr. Headlee's observations show that during 1916 the rosy aphis started to hatch on April 15 in this orchard. Dormant lime-sulfur 1-9 was sprayed on the trees west of the house on March 31, 1917, and on the block east of the house on April 2, 1917. To our surprise, it was discovered that the eggs were actively hatching at this time, but the nymphs proved to be *A. avenæ.* The out-of-door experiments at the laboratory showed some hatch on March 30 and over 20 per cent had hatched by April 2. Mr. Barclay continued to put on the lime-sulfur after

April 2 but added "Black-leaf 40" at the rate of 1-500 in order to kill the nymphs. Lime-sulfur 1-9 alone will not kill all the nymphs of any of the three species. A large number of nymphs and adults of each species were sprayed with lime-sulfur 1-9 in the laboratory and only a few were killed, *A. pomi* being the most susceptible. This also agrees with Dr. Headlee's (9, 10) experiment with *A. sorbi* in 1916, where nymphs lived and apparently did not suffer with lime-sulfur on their bodies. Regardless of the fact that the lime-sulfur was not applied before the eggs of *A. avenæ* started to hatch, an interesting series of observations were made which show conclusively that lime-sulfur is effective in killing the egg during the hatching period. Two collections were made from the trees in the block east of the house before the spray was put on and

TABLE 7

RELATION BETWEEN PERCENTAGE OF HATCH, PERCENTAGE OF NORMAL EGGS AND PERCENTAGE OF SHRIVELED EGGS AMONG SPRAYED EGGS AND EGGS IN CHECK IN TABLE 6

Check (3) Observed Apr. 3	Sprayed Eggs (1) Observed Apr. 4	Difference
28.3% hatched	23.2% hatched	= (a) 5.1% difference in hatch
33% normal	36.3% normal	= (b) 3.3% difference in normal
39% shriveled	40.5% shriveled	= (c) 1.5% difference in shriveled
Equation: (b) 3.3% + (c) 1.5% = (b+c) 4.8%. approximately equals (a) 5.1%.		
Check (4) Observed Apr. 5	Sprayed Eggs (1) Observed Apr. 4	Difference
59% hatched	23.2% hatched	= (a) 35.8% difference in hatch
14% normal	36.3% normal	= (b) 22.3% difference in normal
27% shriveled	40.5% shriveled	= (c) 13.5% difference in shriveled
Equation (b) 22.3% + (c) 13.5% = (b+c) 35.8%, equals (a) 35.8%.		

Note: For complete information read discussion.

the percentage of hatch in these checks was two or three times as great as in the sprayed twigs collected after the lime-sulfur was applied. Table 6 shows the various percentages of hatch and percentages of shriveled and normal eggs found in this portion of the orchard.

If lime-sulfur is a good control measure, then at any period of observation the percentages of hatch on the spray twigs should not show a marked increase over the first observation of April 4 which was made 12 hours after the spray was put on. The first observation on sprayed eggs showed a 23.2 per cent hatch, and a second observation on April 11, which was about five days after all normal eggs had hatched, showed 23.5 per cent hatched, giving a 0.3 per cent increase. On April 14, another collection of twigs

was made and out of 564 eggs, 20.9 per cent had hatched, thus showing conclusively that there was no appreciable increase in hatch after the lime-sulfur was applied. Furthermore, in comparing the percentage of hatch among the sprayed eggs with that of eggs receiving no treatment, it is evident that the following interrelationship between the percentages should hold. If the lime-sulfur acts as a control, then the percentage of hatch will not increase among sprayed eggs, while normal untreated eggs will continue to hatch. The percentage of hatch, then, in sprayed eggs is a constant number. If such is the case, then the difference (a) between the percentage of hatch in sprayed eggs and the percentage of hatch in untreated eggs should at any time equal the difference (b) between the percentage of normal eggs among the sprayed eggs and the percentage of normal eggs among the untreated eggs plus the difference (c) between the percentage of shriveled eggs among the sprayed eggs and the percentage of shriveled eggs among the

TABLE 8

RESULTS OF SPRAYING WITH LIME-SULFUR, AND LIME-SULFUR COMBINED WITH NICOTINE WHEN THE NYMPHS WERE EMERGING AT JOHN H. BARCLAY'S ORCHARD IN 1918

Date Observed	Check		Lime-sulfur 1-9		Lime-sulfur 1-9 "Black-Leaf 40" 1-500	
	Hatched Eggs and Total Eggs	Percentage Hatched	Hatched Eggs and Total Eggs	Percentage Hatched	Hatched Eggs and Total Eggs	Percentage Hatched
April 1	55 h 243	22.0	19 h 191	10.0	27 h 292	9.2
April 8	77 h 243	35.8	29 h 191	15.0	29 h 292	9.6
April 1	150 aphides to 100 buds		5 aphides to 100 buds		0 aphides to 100 buds	
April 5	350 aphides to 100 buds		25 aphides to 100 buds		10 aphides to 100 buds	

untreated eggs. Table 7 shows this comparison for the observations made on April 3, 4 and 5 in experiments 1, 3 and 4. The same relationship will hold for observations made on April 11 and 14, but these have not been included in this discussion.

The figures in table 6 and 7 show that lime-sulfur sprayed on the eggs of *A. avenæ* during the hatching period prevented 99 per cent of the eggs from hatching which had not hatched at the time of application.

Several careful examinations were made throughout the orchard during the month of April and only an occasional aphid could be found, one or two per tree. Nearby orchards along with one unsprayed tree in Barclay's orchard showed a heavy infestation, approximately five aphides to a bud. Examinations made the latter part of May and in June showed practically no *A. avenæ* on trees sprayed with lime-sulfur or combined lime-sulfur and

nicotine, but some of the trees did show a few clusters of curled leaves due to *A. sorbi,* rosy aphis. *A. sorbi* is somewhat more resistant than *A. avenæ.*

During 1918 careful observations were made on spraying operations conducted in several orchards throughout the state. At John H. Barclay's orchard near Cranbury the first nymphs emerged on March 21, and 10 per cent of the eggs had hatched on March 30 when lime-sulfur 1-9 was sprayed on 150 nine-year-old apple trees (Duchess). On April 1 about 80 trees of the same variety were sprayed with a combination of lime-sulfur 1-9 and nicotine 1-500. A large number of twigs were collected from sprayed and unsprayed trees and observed on April 1, about ten hours after the combined spray was applied. Since the nymphs were emerging very rapidly on April 1, the difference between the percentage of hatch in the sprayed and unsprayed twigs observed on April 1 can be in part accounted for in the delay of ten hours before the observations could be made. Table 8 shows the effect of the sprays on the eggs and nymphs when the nymphs were emerging.

On April 8 after all the normal eggs had hatched it was noted that the number of hatched eggs on the unsprayed branches increased 13.5 per cent, while the percentage of hatch among eggs sprayed with lime-sulfur 1-9 showed a 5 per cent increase and those sprayed with a combination of lime-sulfur and nicotine did not increase more than 0.5 per cent. This experiment shows that eggs are killed with lime-sulfur sprays and also brings out the increased effectiveness of a combination spray of lime-sulfur and nicotine over lime-sulfur alone.

The trees were also examined for nymphs. Check trees on April 5 showed 350 aphides to 100 swollen fruit buds, while trees sprayed with lime-sulfur alone showed 25 aphides to 100 buds and the combination sprayed showed 10 aphides to 100 buds. It should also be observed that the lime-sulfur alone did not kill all the nymphs which had emerged at the time the spray was applied, while the combined lime-sulfur and nicotine did kill all the nymphs. Again, the combined spray demonstrated its superiority over lime-sulfur alone as a control measure for nymphs.

The above sprays were applied by means of one "Hardie" gun attached to a sprayer with 225-pounds pressure. The operator stood on the tank and sprayed the trees on each side of the row, thus giving each tree two applications from opposite directions. This type of instrument is very useful and well adapted to dormant spraying when it is necessary to hit all parts of the tree with considerable force.

On March 28 at J. L. Lippincott Company's orchard, at Riverton, N. J., a combination spray of lime-sulfur 1-9 and nicotine

1-500 was sprayed on some early varieties of apple trees (Star, etc.). The fruit buds on these trees were swollen and some were showing the tip ends of very small leaves. Twigs were collected and examined six hours after the spray was applied. The unsprayed twigs showed a 9.5 per cent hatch of all the eggs while the sprayed branches showed 6.3 per cent hatched. Comparing the percentage of hatch of these eggs with those collected near New Brunswick, it is evident that the majority of eggs hatched about 48 hours earlier. This is due to the fact that Riverton is approximately 50 miles south of New Brunswick. The above twigs were examined again after all the normal eggs had hatched (April 8) and the percentage of hatch in the check was 32 per cent, or an increase of 24.5 per cent, while the sprayed eggs showed 8.9 per cent hatched, or an increase of 2.6 per cent. On April 5 the orchard was examined for nymphs and the sprayed trees showed 17 nymphs to 100 fruit buds, while the buds of nearby unsprayed trees were in many cases completely covered with aphides. The above orchard experiment again shows the value of spraying eggs and nymphs at the hatching period with a combined spray consisting of lime-sulfur 1-9 and nicotine 1-500. The proportion of eggs which hatched after they were sprayed in this orchard was about 2 per cent higher than at John Barclay's orchard. This was probably due to the fact that the material was applied by using long rods and putting the material on in the form of a mist. Furthermore, an examination of the trees after the spray was applied showed a less thorough job than at Mr. Barclay's orchard. This difference is possibly due to the different types of instruments used in spraying the two orchards. Other orchards were carefully observed during the delayed dormant spray period and in all cases good results were obtained when the material was applied with extreme care.

After April 18 the decided value of applying a delayed dormant spray of lime-sulfur and nicotine for the control of aphides was not as conclusive this past season as in former seasons, because of the fact that a period of cold stormy weather accompanied by snow and sleet in most parts of the state occurred on April 9 and 10, and this weather killed a large percentage of the newly-hatched nymphs. In fact, some unsprayed orchards which had their swollen fruit buds covered with aphides on April 8 did not suffer from aphis attack after the stormy weather was past. During the past season, a large number of adult coccinellid beetles and larvæ of syrphid flies also were present in most orchards.

The time to apply the dormant spray is very important. As a general rule apply the dormant spray as late as possible, for at this time the greatest number of eggs are split and probably some are hatching, especially eggs of *A. avenæ*. The lime-sulfur can be applied with safety as the buds are swelling (plate 2, fig. B) and

first show green and until the small leaves project like small squirrel ears (plate 2, fig. C). When the young leaves have separated somewhat and appear as distinct structures, then the dormant strength of spray will burn them (plate 2, fig. D). The outline drawings of the twigs show the various stages of development of a fruit spur or terminal bud. Stage A is a dormant twig showing eggs of *A. pomi* scattered over its surface, stage B shows a slightly swollen terminal bud with eggs of *A. avenæ* about the dormant buds and nymphs of *A. avenæ* near the green exposed tip. Stage C is a more advanced stage of a swollen terminal bud and

Plate 2. Fruit buds in different stages of development.

is in the last stage when it is safe to apply a dormant lime-sulfur spray. Nymphs and eggs of *A. avenæ* are shown on this twig. Stage D shows distinct and well separated leaves. The nymphs of aphides, if present on such a twig, would be found to a considerable extent in between the leaves in protected places where it is next to impossible to hit all of them with a contact insecticide. Most varieties of apples with twigs in an advanced state cannot be sprayed with a dormant strength of lime-sulfur without injuring the young leaves. The length of the period from the time when the buds first show green and until they are too far advanced for dormant spray varies with the growing season. It may be less

than a week or more than ten days. In using a combination spray it would be better to apply the material thoroughly somewhat early than to wait too long, for as a rule weather conditions are very changeable during the latter part of March.

Other workers have had some experience with the combination spray. Wilson (24) in 1912 recommended for *A. pomi* and *A. sorbi:* "Spray in the spring just as the buds are opening with lime-sulfur plus 'Black-leaf 40' or 'Black-leaf 40' alone. Spray thoroughly applied at the time when the buds are opening will prevent 95-100 per cent of the aphis infestation. The lime-sulfur should be used winter-strength and the 'Black-leaf 40' added at the rate of 1 part to 900 parts of diluted lime-sulfur". Mr. Wilson does not indicate in his experiments whether the eggs have all hatched or not. In either case the combination will undoubtedly succeed, but nicotine sulfate alone at the strength of 1-900 would not kill many of the eggs, according to our experience.

During the spring of 1916 a number of experiments were conducted in various orchards in the state of New York by P. J. Parrott, H. E. Hodgkiss and F. H. Lathrop (18) with the use of lime-sulfur 1-8 plus ¾ pint of nicotine solution (40 per cent) to 100 gallons of solution. In these experiments, "the spraying was purposely delayed until the eggs had begun to hatch and it is reasonably certain that most of the nymphs had emerged." The results obtained in the various orchards were altogether satisfactory and they agree in large measure with those secured by various orchardists throughout New Jersey. The principal difference, however, is the fact that the eggs of *A. sorbi* had not started to hatch when the material was applied April 8, 1917, at Mr. Barclay's orchard; nevertheless they were killed. In the various experiments conducted in New York it is possible that some of the eggs had not hatched, for according to the authors' own statement they were only "reasonably certain that most of the nymphs had emerged." It may be possible to delay the "dormant spray" in New York orchards until the eggs of all species are hatched, but this is not the case in New Jersey, for the eggs of *A. pomi* and *A. sorbi* in two successive seasons, 1916 and 1917, did not hatch to any extent until the leaf buds had burst and the small leaves were well separated.

Dr. T. J. Headlee (9, 10) in 1916 carried on an extensive series of experiments against the rosy aphis at John H. Barclay's orchard and a brief summary of his data shows that the rosy aphis can best be destroyed by making a dormant treatment with lime-sulfur and following that with a green-bud treatment of "Black-leaf 40" (1-1000) plus soap (2 pounds to 50 gal.), or by delaying the dormant treatment of lime-sulfur until the buds begin to show green, and then applying it mixed with "Black-leaf 40" (1-500). These

results, so far as similar experiments are concerned, agree with those obtained by the author during 1917 and 1918.

MISCIBLE OILS

A considerable amount of investigation has been conducted with various kinds of oils, commercial and otherwise, on the eggs of apple aphides. A number of workers have experimented with crude oil emulsions and miscible oils. The most recent work is by P. R. Jones (12), who in a preliminary report treats of various contact insecticides, but deals particularly with different oils as miscible oils, distillate oil emulsion, asphalt emulsion, crude oil emulsion, etc. His general conclusion in respect to these products is that oils having a specific gravity, 14°-29° Baumé, are much more effective in killing the eggs of aphides than high-gravity oils, 31°-41° Baumé. His recommendation reads, "As far as can be determined at present under western conditions it is believed that dormant treatment for eggs of the apple and purple aphides should be either commercial crude oil emulsion, 1-9 or 1-10 (where the concentrate contains 85 per cent crude oil); home-made crude oil emulsion, 19°-23° Baumé—and the application made as late in the winter as possible before the buds start to show green." He experimented with various miscible oils, some made from low-gravity oils and others from high-gravity oils, and so far as can be learned from his report the above conclusions pertaining to specific gravity of oils in general also hold for miscible oils. His results will be compared with those observed in this study.

No attempt was made by the author to carry on an extensive investigation with various oils, but two commercial miscible oils which are utilized extensively in New Jersey and other eastern states have been tried in a number of experiments, and their results carefully observed. The trade names for these oils are "Mechling's Scale-Oil", manufactured by Mechling Brothers Manufacturing Company, Camden, N. J., and "Scalecide", manufactured by B. G. Pratt Company, New York City. Both of these oils are largely made from oils which have a comparatively low specific gravity; the specific gravity and the information furnished by the two concerns confirms this statement. The specific gravity of "Mechling's Scale-Oil" used in the experiments was 28° Baumé at 65° F., and of "Scalecide" 25° Baumé at 65° F. The B. G. Pratt Company reports, "We use as a petroleum an asphaltum base oil from which the light inflammable and heavy lubricating oils have been removed and which has an oil gravity of about 26°-30° Baumé." The Mechling Brothers Manufacturing Company reports, 'Mechling's Scale-Oil is composed of three entirely different oils, a vegetable oil, a cresote oil and a paraffine oil, the largest part being the latter," and their guaranteed analysis shows 85-88 per cent mineral oil. The specific gravities of these two oils are

about the same, but if there is a difference "Mechling's Scale-Oil" is lighter than "Scalecide."

During March and April, 1917, a number of experiments were conducted with the above-mentioned miscible oils on the eggs of *A. avenæ* in the greenhouse and on the eggs of *A. avenæ, A. pomi* and *A. sorbi* out-of-doors at the laboratory. Also one experiment was conducted with "Scalecide" against the eggs of *A. avenæ* (*A. sorbi,* 15 per cent) at John H. Barclay's orchard. The results of the more important experiments with "Mechling's Scale-Oil and "Scalecide" are shown in table 4. Experiments G-27, 0-29 and 0-31 where "Mechling's Scale-Oil" was used at the rate of 1-19 showed a 6.3, 8.1 and 8.5 per cent hatch, respectively, while "Scalecide" 1-15, in experiments G-34, 0-36, 0-38 and 0-40, showed a 23.0, 34.6, 22.8, and 31.7 per cent hatch, respectively. In other words, three to four times as many eggs hatched when treated with "Scalecide" as with "Mechlings' Scale-Oil."

A comparison of the results obtained in the use of the two miscible oils shows that "Scalecide" 1-15 is not as effective in killing eggs as "Mechling's Scale-Oil" 1-19, and that neither may be depended upon to kill all the eggs or act as a satisfactory control when applied at the strengths recommended for dormant spray. Since both sprays are manufactured from low gravity oils it was impossible to explain the decided difference in the percentage of kill on the basis of the specific gravity of the oil, but it was apparent that some chemical might be present in one which did not occur in the other. In conjunction with the experiments with miscible oils, crude carbolic acid was used alone and in combination with the miscible oils, and it was noted that the eggs of all three species were highly susceptible to cresols and phenol; consequently, it was thought that the presence of these chemicals might explain the difference in the effectiveness of the two oils. In the first place, it was noted that "Mechling's Scale-Oil" had a distinct phenol odor, while this was not true of "Scalecide." The two oils were subjected to two qualitative tests (Landolt's and Lieberman's) (14, 22) for cresols and phenol. "Mechling's Scale-Oil" gave a decided test for cresols and phenol while "Scalecide" gave no indication. A short time after this the two companies kindly submitted an analysis of their respective products. And the manufactures of "Scalecide" definitely stated that their product contained no carbolic acid while Mechling Brothers' Manufacturing Company gave a guaranteed analysis of 4.5 to 6.5 per cent of phenol derivatives for "Mechling's Scale-Oil".

The presence of the phenol derivatives in "Mechling's Scale-Oil" and their absence in "Scalecide" probably accounts in large measure for the decided difference in the effectiveness of the two oils. In all the experiments G-28, 0-30, G-35, 0-37 and 0-39 (table

TABLE 9

EXPERIMENTS WITH "SCALECIDE" AND "SCALECIDE" COMBINED WITH CRUDE CARBOLIC ACID, PHENOL C. P. AND CRESOL U. S. P. ON SELECTED EGGS OF A. AVENAE (Out-of-doors, 1918)

Date sprayed and source of eggs	Feb. 1, 1918 Barclay's		Feb. 19, 1918 Barclay's		March 5, 1918 Lippincott's		March 14, 1918 Barclay's		March 20, 1918 Lippincott's		March 23, 1918 Barclay's	
Spray	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched
"Scalecide" 1-15	30 h 120	25.0	19 h 77	24.6	4 h 92	4.3	29 h 116	25.0	2 h 109	1.8	15 h 115	13.0
"Scalecide" 1-15, Crude Carbolic 1-99					1 h 97	1.0	2 h 127	1.5	0 h 102	0.0	0 h 104	0.0
"Scalecide" 1-15, Cresol 1-99			3 h 102	2.9	0 h 98	0.0	11 h 102	10.7	0 h 94	0.0	1 h 93	1.0
"Scalecide" 1-15, Phenol 1-99			17 h 98	17.3	13 h 84	15.4	43 h 113	38.0	2 h 102	2.0	4 h 90	4.4
"Scalecide" 1-40	18 h 81	22.2	26 h 102	25.4	7 h 94	7.4	27 h 88	30.8	8 h 102	7.8	39 h 102	38.2
"Scalecide" 1-40, Crude Carbolic 1-99					0 h 95	0.0	3 h 97	3.0	0 h 90	0.0	1 h 99	1.0
"Scalecide" 1-40, Cresol 1-99	27 h 81	33.3	3 h 112	2.6	1 h 98	1.0	7 h 110	6.5	0 h 95	0.0	3 h 110	2.7
"Scalecide" 1-40, Phenol 1-99	10 h 59	17.0	23 h 123	18.5	10 h 101	10.0	35 h 102	34.3	9 h 100	9.0	13 h 104	12.5
Check	120 h 175	68.5	80 h 150	53.3	45 h 135	33.3	97 h 212	45.7	89 h 201	44.2	34 h 104	32.6

h—Indicates hatched eggs

4) where crude carbolic acid was added at the rate of 2 parts to 98 of miscible oil spray (making a 2 per cent solution), the percentage of hatched eggs was decreased to 3.9 per cent or a complete kill where "Scalecide" 1-15 was used, and all eggs were killed when the acid was added to "Mechling's Scale-Oil". These results show that miscible oils would be much more effective in killing aphid eggs if crude carbolic acid (principally cresol) derivatives were present.

Comparing the results of the experiment where two heavy miscible oils were used with those obtained by P. R. Jones (12), there is some disagreement. "Scalecide" is unquestionably a low gravity oil and it was used at the same rate as Miscible Oil No. 1, which gave good results in California. This apparent inconsistency in results cannot be explained on the basis of specific gravity, so the question is raised in respect to the presence of phenol or cresols in Miscible Oil No. 1, and also whether these active antiseptic agents were present in the various oils used in the western states where good results were obtained. It is thought that the presence of these chemicals may prove to be far more important than the mere specific gravity of the oil. Possibly one can add crude carbolic acid to oils in general and increase their insecticidal value.

In 1918 a number of experiments were conducted during February and March with "Scalecide" at varying strengths and in combination with crude carbolic acid, cresol U. S. P., and phenol c. p. on the eggs of *A. avenæ* out-of-doors at the laboratory. The purpose of these experiments was to determine what material in crude carbolic acid is the most effective agent in killing aphid eggs and how much acid should be added to a miscible oil in order that it might kill 100 per cent of all the eggs with which it came in contact. "Scalecide" was chosen as a favorable oil, for chemical tests show that there was little or no carbolic acid of phenol derivatives present in it. Table 9 shows in condensed form the results of these experiments. In the left-hand column the treatments of the series are given, and at the top the date of the spraying and the orchard from which the eggs were collected. In the two spaces for each experiment there are shown the number of hatched eggs (h), the total number of eggs used, and the percentage of hatch.

The results of the experiments with "Scalecide" show considerable variation in the respective series, more so than in any other series of experiments with other sprays. These somewhat inconsistent results are not understood; however, if one studies the table it is seen that the eggs are most susceptible to "Scalecide" (alone or in combination with the acids) near the time when the nymph emerges, or in other words, when the greatest number of eggs show a split outer covering. "Scalecide" 1-15 is more effective

than "Scalecide" 1-40 but when crude carbolic acid or cresol is combined with these two strengths the difference between the results is not as marked. Crude carbolic acid (100 per cent acid), 1 part to 99 parts of spray, combined with "Scalecide" 1-15 makes the most effective (100 per cent) kill and also the cheapest killing agent of the three acid combinations tried out. Combinations with cresol U. S. P. are almost as effective as crude carbolic but combinations with phenol c. p. are the least effective and also the most expensive.

TABLE 10

EXPERIMENTS WITH "SCALECIDE" COMBINED WITH CRESOL* ON SELECTED EGGS OF A. AVENAE COLLECTED FROM J. L. LIPPINCOTT AND COMPANY; OUT-OF-DOORS; SPRAYED MARCH 26, 1918

Number of Experiment	Spray	Total Eggs	Total Hatch	Percentage Hatched
331	Check	106	57	53.7
332	"Scalecide" 1-15	106	9	8.4
333	"Scalecide" 1-15, plus cresol 0.5%	75	2	2.6
334	"Scalecide" 1-15, plus cresol 1%	85	0	0.0
335	"Scalecide" 1-15, plus cresol 1.5%	82	0	0.0
336	"Scalecide" 1-25	112	16	14.2
337	"Scalecide" 1-25, plus cresol 0.5%	83	2	2.4
338	"Scalecide" 1-25, plus cresol 1%	91	3	3.3
339	"Scalecide" 1-25, plus cresol 1.5%	90	1	1.1
340	"Scalecide" 1-40	88	7	7.9
341	"Scalecide" 1-40, plus cresol 0.5%	93	2	2.1
342	"Scalecide" 1-40, plus cresol 1%	93	1	1.0
343	"Scalecide" 1-40, plus cresol 1.5%	103	0	0.0

*The cresol was composed of one part meta-cresol, one part ortho-cresol and one part para-cresol.

Another set of experiments, shown in table 10, were conducted on March 26, 1918 with "Scalecide" 1-15, 1-25 and 1-40 alone and each in combination with 0.5, 1.0 and 1.5 per cent cresol. The cresol mixture was made up of one part meta cresol, one part ortho cresol and one part para cresol. These experiments show again a decided increase in the effectiveness of the "Scalecide" when cresol is added. In all cases the 1.5 per cent cresol combinations showed the smallest percentage of hatch, in two experiments a complete kill. The experiments also show that the percentage of hatch in the various strengths of "Scalecide" (alone) varies more than when the same strength of "Scalecide" has a given amount of cresol added to it. In other words, the strength of the oil when in combinations with cresol is not as important as the strength of the cresol. This same thing holds true for crude carbolic when combined with a miscible oil.

Comparing these foregoing experiments with miscible oils and others of a similar nature conducted this past season with those of 1917, it is evident that a miscible oil spray needs to possess 1.5 to 2.0 per cent crude carbolic acid or cresol as it goes on the tree in

order to kill all the eggs of *A. avenæ*. Eggs of *A. pomi* and *A. sorbi* also respond in a similar manner to combinations of "Scalecide" and crude carbolic acid; however, they are apparently somewhat more resistant, and consequently more will hatch.

In the orchard "Scalecide" 1-15 was given a trial at John H. Barclay's place in 1917 in conjunction with a combined spray of lime-sulfur 1-9 and "Black-leaf 40" 1-500. During the morning of April 7, Mr. Barclay sprayed 100 large apple trees with "Scalecide" 1-15. The buds were swollen and some of the leaves were out about ¼ inch. These trees at the time of spraying averaged five nymphs of *A. avenæ* per bud. A careful examination was made of several hundred buds at 5 o'clock the afternoon of the same day, and at this time the nymphs averaged 1 living aphid to 25 buds; in other words, the "Scalecide" killed 99 per cent of the nymphs. These trees were again examined on April 14 when the leaves were out ½ to ¾ inch long, and at this time the nymphs averaged one to every two buds, but these were mostly nymphs of *A. sorbi*. Out-of-door laboratory experiments conducted during this period showed that all eggs of *A. avenæ* had hatched by April 6 or 7, and the eggs of *A. sorbi* commenced to hatch about April 12. According to these data the eggs of *A. sorbi* hatched after April 7, and "Scalecide" did not prevent all the eggs of this species from hatching. In fact, the infestation was severe enough to demand the use of "Black-leaf 40" 1-500 when the lime-sulfur 1-40 was applied at the pink-bud stage. Even though this measure of precaution was taken the results were by no means satisfactory.

In contrast to the above experiment, lime-sulfur 1-9 plus "Black-leaf 40" 1-500 was applied to about one hundred infested trees (5 nymphs to the bud) on April 7, and an examination made in the afternoon of the same day showed that so many of the nymphs had been killed that none could be found. A vast majority of the eggs of *A. sorbi* also were killed, for no nymphs could be found on April 14; however, a very few did survive, for in the latter part of May and in June an occasional tree showed a few clusters of leaves infested with *A. sorbi*, but the majority of the trees were entirely clean. The trees treated with "Scalecide" on April 7 and later sprayed with lime-sulfur 1-40 plus "Black-leaf 40" showed during May and June a comparatively heavy infestation. No tree was completely free and in many a considerable amount of fruit was damaged. One tree which had received no dormant treatment or nicotine sulfate served as a check, and this tree was severely infested, over 75 per cent of the leaves being badly curled and a large percentage of the fruit ruined. These experiments, along with those conducted at the laboratory, show the superiority of lime-sulfur 1-8 or 1-9, plus "Black-leaf 40"

1-500 over "Scalecide" 1-15 for the control of aphids in the nymph and egg stage. They also bring out the fact that a most careful attempt to "clean up" aphis by adding 40 per cent nicotine to summer strength lime-sulfur at the cluster-cup or pink-bud stage will at times fail.

A few young trees not over six years old were sprayed with "Scalecide" 1-15 plus crude carbolic acid, 1 part to 99 of the spray (1 per cent solution), on March 18, 1918. These were carefully observed at the time the leaves came out. On most of the branches of the sprayed trees the leaves appeared to be normal, but on a few of the lower branches the buds were backward in opening and some seemed to be dead. Before the combination of "Scalecide" and crude carbolic acid can be recommended as a dormant spray for killing aphid eggs, it will be necessary to give this combination a thorough trial and note its effect upon various varieties of apple trees.

SOAPS

Common laundry soap, commercially called "Fels Naptha", and fish-oil soaps (made from commercial liquid and solid forms) were used chiefly as spreaders in a large number of experiments with nicotine, crude carbolic acid, phenol c. p., cresol U. S. P., meta cresol c. p., ortho cresol c. p., para cresol c. p., etc. In all these experiments the soap was always given a separate trial in order to determine its influence on the percentage of hatch. Besides using laundry soap as a spreader, a large number of experiments were conducted with different concentrations of fish-oil soap (made from both solid and liquid forms) and resin fish-oil soap on the eggs of *A. avenæ* in out-of-door experiments throughout February and March, 1918. In the majority of experiments (tables 4 etc.) where the soaps were used at the rate of 1 gm. to 200 cc. (1 pound to 24 gallons) there was a slight reduction in the percentage of hatch. This can be seen by comparing the percentage of hatch among the sprayed eggs with the respective checks. Even though this reduction was small it demonstrates the fact that some of the eggs of each species are much less resistant than others.

A limited number of experiments were conducted in 1917 with fish-oil soap (exp. G-61 to G-63 and 0-64 to 0-67, table 4) and the results indicated that this soap was very effective when in concentrated form. The results of these experiments, however, were questioned, for unfortunately they were dislodged by a heavy wind and covered with snow for two days before the accident was discovered. In spite of this unfortunate occurrence, these experiments and others indicated that it would be advisable to make an extensive study of the effect of different strengths of fish-oil soap on the

TABLE 11

EXPERIMENTS WITH FISH-OIL SOAP SPRAYS (MADE FROM SOLID AND LIQUID FORMS) ON SELECTED EGGS OF A. AVENAE; OUT-OF-DOORS, 1918

Date Sprayed and Source of Eggs	Feb. 19, 1918 Barclay's		Mar. 4, 1918 Lippincott's		March 14, 1918 Barclay's		March 19, 1918 Lippincott's		March 22, 1918 Barclay's	
Spray	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched
Check	80 h 150	53.3	45 h 135	33.3	97 h 212	45.7	89 h 201	44.2	34 h 104	32.6
Fish-Oil Soap (solid) 1 gm.-200 cc.	14 h 106	62.7	25 h 89	28.0	40 h 97	41.2	42 h 82	51.2	18 h 103	17.4
Fish-Oil Soap (solid) 1 gm.-100 cc.			47 h 131	35.8	34 h 92	36.9	31 h 78	39.7	23 h 102	22.5
Fish-Oil Soap (solid) 1 gm.-50 cc.	54 h 111	48.6	27 h 107	25.2	23 h 100	23.3	53 h 105	50.4	14 h 90	15.5
Fish-Oil Soap (solid) 1 gm.-25 cc.	31 h 89	34.8			19 h 105	18.1			7 h 97	7.2
Fish-Oil Soap (liquid) 1 cc-200 cc.	47 h 101	46.8			45 h 102	44.1			35 h 107	32.7
Fish-Oil Soap (liquid) 1 cc-50 cc.	27 h 94	28.7			53 h 125	42.4	67 h 112	59.8	28 h 101	27.8
Fish-Oil Soap (liquid) 1 cc-25 cc.	59 h 115	51.3			40 h 105	38.0	42 h 91	46.1	31 h 127	24.4
Fish-Oil Soap (liquid) 1 cc-10 cc.							28 h 92	30.4	20 h 108	18.5

h—indicates hatched eggs.

TABLE 12

EXPERIMENTS WITH RESIN FISH-OIL SOAP ON SELECTED EGGS OF A. AVENAE, OUT-OF-DOORS, 1918

Date sprayed and Source of Eggs	Feb. 1, 1918 Barclay's		Feb. 19, 1918 Barclay's		March 4, 1918 Lippincott's		March 14, 1918 Barclay's		March 22, 1918 Barclay's	
Spray	Hatched and Total Eggs	Percentage Hatched	Hatched Eggs and Total	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched
Resin fish-oil soap 1 gm.-200 cc.	25 h 85	28.0	54 h 108	50.0	38 h 94	39.5	57 h 118	48.3	46 h 117	39.3
Resin fish-oil soap 1 gm.-100 cc.	32 h 82	39.0			33 h 90	36.6	56 h 93	60.2	52 h 120	43.3
Resin fish-oil soap 1 gm.-50 cc.	35 h 67	52.2	43 h 89	48.3	44 h 92	47.7	23 h 85	27.0	23 h 100	23.0
Resin fish-oil soap 1 gm.-25 cc	25 h 75	33.3	41 h 94	43.5			17 h 54	31.4	19 h 128	14.8
Check	78 h 173	45.0	80 h 150	53.3	45 h 135	33.3	97 h 212	45.7	34 h 104	32.6

h—indicates hatched eggs

eggs of apple aphides, consequently a large number of experiments were conducted with varying concentrations of fish-oil soap sprays (made from solid and liquid soaps) and resin fish-oil soap on the eggs of *A. avenæ* out-of-doors at the laboratory during February and March, 1918. The results of these experiments are given in the usual manner in tables 11 and 12.

These experiments recorded in table 11 and others of a similar nature show that fish-oil soap sprays made from either the solid or liquid form are quite effective in killing aphid eggs. Similar concentrations of laundry soap are not as effective as the fish-oil soaps. Comparing the effectiveness of the same concentration of fish-oil soap sprays made from solid and liquid fish-oil soap, the percentage of hatch was much less where the fish-oil soap spray was made from solid fish-oil soap.[2]

Resin fish-oil soap (table 12) was also given a thorough trial in a set of experiments similar to the above, and the results of the experiments show that resin fish-oil soap is not as effective in killing eggs as the same concentration (by weight) of fish-oil soap sprays made from solid fish-oil soap. The lowest percentage of hatch with resin fish-oil soap, 1 gm. to 25 cc., applied on March 22, was 14.8 per cent, while a similar concentration of fish-oil soap made from solid soap reduced the percentage of hatch to 7.2 per cent when applied on the same day.

All the series of experiments (soap of same concentration) with the various soaps show the greatest percentage of kill or the smallest percentage of hatch when the spray was applied near the time when the nymph emerges. In other words, the exposed pigmented layer of the eggs is more pervious to soap solutions than the outer tough layer. This observation again substantiates a former statement made in discussing contact insecticides; when the greatest number of eggs show a split-out shell, then the greatest number of eggs will be most susceptible to various contact insecticides. The greatest number of eggs with a split outer covering occurs at the time when the first nymphs emerge.

Nicotine

A number of experiments have been conducted with nicotine as found in the commercial products called "Black-leaf 40" and "Nicotine resinate" (40 per cent nicotine in each). These are manufactured by the Kentucky Tobacco Products Company, Louisville, Ky. In 1917 the "Black-leaf 40" was applied on the eggs of *A. avenæ* out-of-doors at the laboratory on April 3 (exp. 0-41

[2]The solid and liquid fish-oil soaps were purchased from Capstone Manufacturing Co., Newark, N. J., and the resin fish-oil soap from James Good, Philadelphia, Pa.

TABLE 13

EXPERIMENTS WITH NICOTINE, "BLACK-LEAF 40", COMBINED WITH FISH-OIL SOAP (solid) AND NICOTINE RESINATE ON SELECTED EGGS OF A. AVENAE; OUT-OF-DOORS, 1918

Date Sprayed and Source of Eggs	Feb. 19, 1918 Barclay's		Mar. 4, 1918 Lippincott's		Mar. 14, 1918 Barclay's		Mar. 19, 1918 Lippincott's		Mar. 22, 1918 Barclay's	
Spray	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched
"Black-leaf 40" 1-500, F. O. soap (s) 1 gm.-200 cc.	41 h 96	42.7	28 h 108	25.9	46 h 107	42.9	32 h 98	32.6	24 h 103	23.3
"Black-leaf 40" 1-500, F. O. soap (s) 1 gm.-100 cc.			16 h 96	16.6	37 h 124	29.8	14 h 91	15.3	9 h 94	8.5
"Black-leaf 40" 1-500, F. O. soap (s) 1 gm.-50 cc.	17 h 60	28.3	9 h 101	9.0	15 h 145	10.3	4 h 92	4.3	0 h 107	0.0
"Black-leaf 40" 1-500, F. O. soap (s) 1 gm.-25 cc.	14 h 106	13.2			2 h 108	1.8			0 h 119	0.0
Nicotine resinate 1 cc.-1000 cc.	50 h 103	48.5	42 h 121	34.7	25 h 110	22.7	22 h 81	27.1	26 h 110	23.6
Nicotine resinate 1 cc.-500 cc.	46 h 93	49.4	31 h 105	29.5	20 h 112	17.8	9 h 94	12.1	17 h 146	11.6
Nicotine resinate 1 cc.-250 cc.	30 h 104	28.8			18 h 82	21.9			6 h 110	5.4
Check	80 h 150	53.3	45 h 135	33.3	97 h 212	45.7	89 h 201	44.2	34 h 104	32.6

h—indicates hatched eggs; s—indicates solid fish-oil soap.

to 0-44, table 4) at the rate of 1-100, 1-250 and 1-500, and laundry soap (1 gm. to 200 cc.) was used as a spreader. The percentages of hatch in the check and in the experiment where the laundry soap was tried alone were approximately the same, 40 per cent and 39.2 per cent, respectively; consequently the soap must have had very little effect on the percentage of hatch when combined with the nicotine. The percentage of hatched eggs was reduced in all the experiments with the nicotine. Where the nicotine was used at the rate of 1-500 the percentage of hatch was 22.4 per cent, or 17.6 per cent lower than in the check. The greater strengths of nicotine showed a still greater reduction. According to the above experiment with "Black-leaf 40" 1-500, when combined with enough laundry soap to act as a spreader, the reduction in the number of hatched eggs is not sufficient to warrant the use of the same as a control measure. Greater strengths than 1-500 are prohibitive on account of the cost.

During the dormant season of 1917-18 a number of experiments were conducted with "Black-leaf 40" combined with lime-sulfur 1-9, fish-oil soap and resin fish-oil soap. In all but one or two of these experiments the combined spray was considerably more effective than the lime-sulfur, fish-oil soap, or resin fish-oil soap alone. This was particularly true when the combined spray was applied near the time when the nymph emerges, or in other words, when the greatest number of eggs show a split outer shell. The superiority of a combined nicotine and lime-sulfur spray over lime-sulfur alone has been considered under the discussion on lime-sulfur.

The experiments with the combinations of "Black-leaf 40", and fish-oil soap sprays made from solid soap show the greatest percentage of kill, 100 per cent, where the "Black-leaf 40" 1-500 was combined with fish-oil soap, 1 gm. to 50 cc. (= 1 pound to 6 gallons), or 1 gm. to 25 cc. (= 1 pound to 3 gallons), and sprayed on the eggs of *A. avenæ* as they started to emerge, March 22. Fish-oil soap alone at the same respective strengths and applied on the same day killed only 85 and 92 per cent of the eggs. A comparison of the results in the two tables (11 and 13) shows the relative superiority of a combined spray of nicotine and fish-oil soap over fish-oil soap alone.

A number of experiments were conducted also with nicotine combined with fish-oil soap sprays made from liquid fish-oil soap, and with similar concentrations (by weight) the percentage of kill was not as great as with fish-oil soap made from solid soap. This is undoubtedly due to the fact that commercial liquid fish-oil soap possesses a considerable portion of water (60-70 per cent); consequently, there is not as much soap present when diluted to the desired strength.

A few experiments were conducted with combinations of nicotine and resin fish-oil soap, and these indicate that resin fish-oil soap is not as effective in combination with nicotine as fish-oil soap made from solid soap.

Nicotine resinate, containing 40 per cent nicotine, was also given a thorough trial during February and March, 1918, on the eggs of *A. avenæ* out-of-doors at the laboratory (table 13). This material behaves like a soap solution and has good spreading and lasting qualities. Nicotine resinate is more effective in killing aphid eggs than "Black-leaf 40" combined with weak solutions of laundry soap. Nicotine resinate at the rate of 1-500 killed 88.4 per cent when the material was applied on March 22, while the same amount of nicotine in "Black-leaf 40" combined with fish-oil soap (solid form), 1 gm. to 50 cc. killed 100 per cent (0.0 per cent hatched).

All the experiments where nicotine is used show that some eggs are killed with nicotine and where nicotine is combined with lime-sulfur, fish-oil soaps, resin fish-oil soap and resin (nicotine resinate) the percentage of kill is increased, and in a few experiments no eggs survived. The experiments also show that the greatest number of eggs of *A. avenæ* are most susceptible to nicotine during the latter part of March, or in other words, when the largest number of eggs show a split outer covering. This brings out the significant relationship between the time of application of the spray, the behavior and structure of the outer semi-transparent layer of the egg, and the susceptibility of the eggs to certain contact insecticides.

CRUDE CARBOLIC ACID, PHENOL AND CRESOLS

During the past two seasons a large number of experiments were conducted with eggs on twigs in the greenhouse, out-of-doors at the laboratory and on young apple trees in the orchard with crude carbolic acid, phenol c. p. cresol U. S. P., meta cresol c. p., ortho cresol c. p., and para cresol c. p. The eggs of all three species of aphides were experimented with in 1917, but only those of *A. avenæ* were obtainable during the past dormant season (1917-18). The results of the following experiments recorded in the various tables show that crude carbolic acid gives some promise of becoming an important substance for the control of aphides in the egg stage, provided it is applied when the tree is dormant.

During March and April, 1917, crude carbolic acid only was used and not any of the pure cresols or phenol. The crude acid had a dark brown color and was approximately 100 per cent acid (no water). It was purchased from Eimer and Amend, New York City, at 60 cents per gallon (ante bellum price). According to Merck and Company, Manufacturing Chemists, this crude carbolic

TABLE 14

EXPERIMENTS WITH CRUDE CARBOLIC ACID, CRESOL U. S. P., PHENOL c. p., META CRESOL c. p., ORTHO CRESOL c. p., AND PARA CRESOL c. p., ON SELECTED EGGS OF A. AVENAE; LAUNDRY SOAP USED AS A SPREADER; OUT-OF-DOORS, 1918

Date Sprayed and Source of Eggs	Dec. 25, 1917 Barclay's		Feb. 23, 1918 Barclay's		Mar. 5, 1918 Lippincott's		Mar. 13, 1918 Barclay's		Mar. 25, 1918 Barclay's	
Spray	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched
Check	120 h 175	68.5	99 h 202	49.0	45 h 135	33.3	116 h 241	48.1	57 h 123	46.3
Laundry Soap (Fels Naptha) 1 gm. to 200 cc.	51 h 92	55.4	42 h 81	51.8	52 h 100	52.0	47 h 110	42.7	32 h 77	44.4
Crude Carbolic, 1%, Laundry soap, 1 gm.-200 cc.					26 h 99	26.2	73 h 106	68.2	11 h 100	11.0
Cresol U. S. P., 1%, Laundry soap, 1 gm.-200 cc.	82 h 125	65.6	41 h 103	39.8	39 h 107	36.4	31 h 112	27.6	33 h 103	32.0
Phenol c. p., 1%, Laundry soap, 1 gm.-200 cc.	55 h 94	58.5	31 h 96	32.2	21 h 83	25.3	53 h 77	68.8	32 h 99	32.4
Meta cresol c. p., 1%, Laundry soap, 1 gm.-200 cc.			53 h 98	54.0	18 h 89	20.2	49 h 101	49.0	31 h 105	29.5
Ortho cresol c. p., 1%, Laundry soap, 1 gm.-200 cc.	48 h 109	44.0	23 h 109	21.1	28 h 98	28.5	60 h 111	54.0	30 h 103	29.1
Para cresol c. p., 1%, Laundry soap, 1 gm.-200 cc.	48 h 93	48.3	36 h 104	34.6	18 h 85	21.1	59 h 116	50.8	26 h 100	26.0

h—indicates hatched eggs.

consisted chiefly of the three isomeric cresols and possibly some xylenol and higher homologues. The crude form used in the following experiments may have also contained some phenol. No quantitative tests were made of this acid, but the extensive experiments conducted with pure phenols and with all three isomeric cresols during 1918 show the relative value of each constituent of crude carbolic acid in respect to killing aphid eggs. The crude carbolic acid at varying strengths, 0.5, 1, 2, 5 and 10 per cent, was used in experiments G-46 to G-51 and 0-52 to 0-58 (table 4) and in all cases a small quantity of soap was used as a spreader. These experiments show an increase in the effectiveness of the spray as the strengths of the acid was increased. Strengths less than 2 per cent acid did not kill a sufficient number of eggs to be considered effective, while strengths greater than 2 per cent acid killed all eggs, and a 2 per cent acid spray killed 96 to 100 per cent. Some experiments where a small amount of fish-oil soap was used as a spreader also were tried with varying strengths of crude carbolic acid, and the results obtained were similar to the foregoing experiments.

In combining crude carbolic acid with soap solutions, it was noted that the crude acid mixes more readily with a fish-oil soap solution than with a laundry soap ("Fels Naptha") solution, and also when thoroughly mixed with a fish-oil soap solution it will remain constant throughout for a considerable period. In preparing mixtures of crude carbolic acid and soap solutions it was advantageous to mix the acid thoroughly with two or three times its volume of soapy water, and then make the desired dilution. Fish-oil soap is also superior to laundry soap in that it has greater insecticidal properties.

The results of the experiments for 1917 indicated that it would be worth while to make a similar but more extensive study of the various isomeric cresols and phenol which go to make crude carbolic acid and note the effect of each on the eggs of aphides. This was undertaken during the past season, with crude carbolic acid, cresols and phenol at varying strengths and in combinations with different strengths of fish-oil soap, such as solid fish-oil soap, liquid fish-oil soap and resin fish-oil soap.

In the first place, a number of experiments were conducted from December 15 to March 25, 1918, with a 1 per cent solution (1 part to 99 of soapy water) of crude carbolic acid, phenol c. p., cresol U. S. P., meta cresol c. p., ortho cresol c. p., and para cresol c. p.; laundry soap ("Fels Naptha") being used at the rate of 1 gm. to 200 cc. The purpose of these experiments was to determine the relative killing effect of the various acids on the eggs of *A. avenæ*. The experiments show that the soap solution alone had little or no effect upon eggs, for the percentage of hatch in the

TABLE 15

EXPERIMENTS WITH CRUDE CARBOLIC ACID, CRESOL U. S. P., AND PHENOL C. P., COMBINED WITH DIFFERENT STRENGTHS OF FISH-OIL SOAP (solid soap) ON SELECTED EGGS OF A. AVENAE; OUT-OF-DOORS, 1918

Date Sprayed and Source of Eggs	Mar. 1, 1918 Barclay's		Mar. 5, 1918 Lippincott's		Mar. 14, 1918 Barclay's		Mar. 23, 1918 Barclay's	
Spray	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatched and Total Eggs	Percentage Hatched	Hatcned and Total Eggs	Percentage Hatched
Check	99 h 202	49.0	45 h 135	33.3	97 h 212	45.7	57 h 123	46.3
Fish-Oil Soap (solid), 1 gm.-100 cc.			47 h 131	35.8	34 h 92	36.9	23 h 102	22.5
Crude Carbolic, 0.5%, Fish-Oil Soap 1-100	51 h 127	40.1	33 h 86	38.3	29 h 107	27.1	8 h 113	7.0
Crude Carbolic, 1%, Fish-Oil Soap 1-100	37 h 138	26.8	14 h 104	13.4	19 h 112	16.9	13 h 111	11.7
Crude Carbolic, 1.5%, Fish-Oil Soap 1-100	22 h 125*	17.6			13 h 114	11.4	4 h 117	3.4
Cresol U. S. P., 0.5%, Fish-Oil Soap 1-100	48 h 119	40.3	24 h 105	22.8	30 h 111	27.0	16 h 108	15.1
Cresol U. S. P., 1%, Fish-Oil Soap 1-100	49 h 107	45.7	22 h 105	20.9	24 h 119	20.1	10 h 106	9.4
Cresol U. S. P., 1.5%, Fish-Oil Soap 1-100	52 h 133*	39.8			9 h 110	8.1	9 h 109	8.2
Phenol c. p., 0.5%, Fish-Oil Soap 1-100	64 h 138	46.3	36 h 115	31.3	32 h 95	33.6	40 h 112	35.7
Phenol c. p., 1%, Fish-Oil Soap 1-100	42 h 126	33.3	36 h 104	34.5	27 h 105	25.7	24 h 91	26.3

Phenol c. p., 1.5%, Fish-Oil Soap 1-100	41 h 121*	33.8			14 h 101	14.0	12 h 105	11.4
Fish-Oil Soap (solid), 1 gm.-50 cc.	54 h 111	48.6	27 h 107	25.2	23 h 100	23.0	14 h 90	15.5
Crude Carbolic, 0.5%, Fish-Oil Soap 1-50	37 h 131	28.2	25 h 116	21.5	39 h 126	30.9	1 h 121	3.3
Crude Carbolic, 1%, Fish-Oil Soap 1-50	35 h 120	29.1	15 h 117	11.9	23 h 115	20.0	4 h 136	3.7
Crude Carbolic, 1.5%, Fish-Oil Soap 1-50	18 h 126*	14.2			25 h 100	23.8	0 h 138	0.0
Cresol U. S. P., 0.5%, Fish-Oil Soap 1-50	52 h 124	41.9	20 h 96	20.8	15 h 65	23.0	14 h 96	14.3
Cresol U. S. P., 1%, Fish-Oil Soap 1-50	41 h 138	29.7	37 h 98	37.7	37 h 113	32.7	12 h 112	10.7
Cresol U. S. P., 1.5%, Fish-Oil Soap 1-50	28 h 100*	28.0			25 h 81	30.9	11 h 114	9.6
Phenol c. p., 0.5%, Fish-Oil Soap 1-50	25 h 166	23.4	15 h 105	14.2	16 h 74	21.6	28 h 112	25.0
Phenol c. p., 1%, Fish-Oil Soap 1-50	30 h 114	26.2	42 h 111	37.8	18 h 103	17.4	11 h 106	10.3
Phenol c. p., 1.5%, Fish-Oil Soap 1-50	42 h 128*	32.6			33 h 140	23.5	12 h 116	10.3

h—indicates hatched eggs.
*In these experiments the crude carbolic acid, cresol or phenol was 2.5 per cent by mistake.

various checks corresponds with the percentage of hatch where the laundry soap was used at the rate of 1 gm. to 200 cc.

The results of the experiments with a 1 per cent solution of the various acids are not very conclusive, and they are also somewhat inconsistent. This is probably due to the fact that a 1 per cent solution is not strong enough to produce an appreciable amount of actual kill, especially when applied early in the season. A 2 per cent solution probably would have given better results, at least the experiments conducted in 1917 indicate as much. Even though the 1 per cent solution did not produce a great amount of kill, nevertheless the smallest percentage of hatched eggs occurred when the spray was applied in the latter part of March near the time when the nymphs emerge.

In order to determine the effectiveness of the varying strengths of crude carbolic acid, cresol U. S. P., and phenol C. P. with fish-oil soap, a large number of experiments were conducted out-of-doors at the laboratory throughout the month of March, 1918. The acids were used in three different strengths 0.5, 1, and 1.5 per cent, and the fish-oil soap solutions (made from solid soap) in two strengths: 1 gm. to 100 cc. (= 1 pound to 12 gallons) and 1 gm. to 50 cc. (= 1 pound to 6 gallons). All possible combinations were made between the three strengths of each acid and the two strengths of the fish-oil soap. Table 15 shows in condensed form, similar to foregoing tables, the treatment given, time of application, source of the eggs, number of hatched eggs (h), total number of eggs and the percentage of hatch.

A general survey of the results of the experiments in table 15 again brings out the point that a contact insecticide applied late in March just before the nymphs emerge will kill the greatest number of eggs. In the four trials with each strength of acid on March 1, 5, 14 and 23 the smallest percentage of hatch occurred where the applications were made on March 14 and 23, and in most cases when applied on March 23. These results indicate that the acid can more readily penetrate to the embryo through the pigmented layer alone (after the outer shell splits) than through both layers when the outer covering is whole. The greatest number of eggs showed a split outer covering on March 23.

A comparison of the effectiveness of the three acids at similar strengths shows that crude carbolic acid killed the largest percentage and phenol the least while cresol U. S. P. was almost as effective in some experiments as crude carbolic acid. A comparison of all the experiments, where the acids composed 1.5 per cent of the spray, brings out the respective effectiveness of the three acids. Why the crude carbolic acid should be the most effective is un-

known. The greatest strength, 1.5 per cent, of the three was the most effective. Furthermore, whenever the same strength of one acid was used with the two different strengths of fish-oil soap the greatest percentage of kill took place when the stronger fish-oil soap, 1 gm. to 50 cc., was used.

If all the above facts are consistent throughout then the one experiment where crude carbolic acid composed 1.5 per cent of the spray combined with a fish-oil soap solution, 1 gm. to 50 cc., and applied on March 23, should show the smallest percentage of hatch. This is the actual case, for the experiment, which fulfills the above requirements, is the only one in the entire lot which shows no hatch, or 100 per cent kill. All other experiments showed some hatch. If the above requirements were fulfilled in orchard spraying it would be possible to control the aphis with this spray. These experiments and others not shown in this paper indicate that a 2 per cent solution of crude carbolic acid combined with a strong fish-oil soap solution would come nearer to controlling aphides in the stage than a 1 or 1.5 per cent acid solution.

A somewhat similar series of experiments (not shown in the table form) were conducted with crude carbolic acid, cresol U. S. P., and phenol c. p., combined with fish-oil soap solution which had been made from liquid fish-oil soap. In these experiments the effectiveness of the combination between the acid and the fish-oil soap was decreased as the strength of the fish-oil soap was increased. This apparent inconsistency was probably due to the fact that the liquid fish-oil soap is strongly basic, and this basic condition of the soap neutralized the acid as its strengtlr was increased.

Similar combinations between the three acids and resin fish-oil soap were tried, but these were not extensive enough to warrant a conclusive statement concerning their effectiveness. A comparison of these results with combinations of the acids and fish-oil soap solutions made from solid fish-oil soap showed that the effectiveness of the combinations between the acids and the resin fish-oil soap was somewhat less than when the acids were combined with fish-oil soap solutions made from solid soap.

The effect of crude carbolic acid on various fruit trees during the dormant season has never been determined, so far as is known; consequently it was necessary to conduct some preliminary experiments along this line. Six apple trees were experimented on, one old tree and five 6-year-old trees. On April 2, 1917, two of the 6-year-old trees and a portion of the mature tree were sprayed with a 2 per cent solution of crude carbolic acid plus laundry soap at the rate of 1 pound to 24 gallons of water. During the same day two 6-year-old trees were sprayed with a 5 per cent solution of crude carbolic acid with laundry soap as a spreader. One 6-year-

old tree and the unsprayed portion of the old tree served as checks. Frequent observations were made of these trees during the period between the bursting of the leaf and the fruit buds and to full blossom and, so far as could be observed, no injury was found on any of the trees. Similar experiments were conducted on March 18, 1918, with fish-oil soap, 1 pound to 6 gallons of water, plus cresol U. S. P. 2 per cent (2 parts to 98 of solution), and again no injury could be detected. On the basis of the above experiments, apparently one can safely apply on dormant trees a spray composed of 2 per cent crude carbolic acid plus fish-oil soap.

VARIOUS CHEMICALS

Sodium sulfo-carbonate having a specific gravity of 35° Baume was tried in one set of experiments (G-3, G-76 and G-77, table 4). The effect of this material on the eggs is similar to that of dormant strength lime-sulfur. The proportion of hatched eggs was 15.3 per cent with a 1-19 dilution, and 2.6 per cent with a 1-9 dilution, while the check showed 62.8 per cent hatched. These results are similar to those obtained when lime-sulfur was used, and it is possible that sodium sulfo-carbonate as a spray might be used with as much success as lime-sulfur.

Sodium chloride (common salt) was experimented with at the rate of 1 gm. to 5 cc. of water on the eggs of *A. avenæ* in the greenhouse (exp. G-4 and G-75, table 4) and out-of-doors (exp. 0-6 and 0-74, table 4) and the proportion of hatched eggs was somewhat lower among the sprayed eggs than in the respective checks. This shows that sodium chloride may prevent the less resistant eggs from hatching. Common salt in combination with lime-sulfur apparently does not materially increase or decrease the effectiveness of the lime-sulfur spray, according to the results in experiments G-17, 0-20 and 0-21 (table 4).

Sodium hydroxide at the rate of 2 gm. to 98 cc. of water has a decided influence on the percentage of hatch of the eggs of *A. avenæ* in the greenhouse and out-of-doors. In experiments 0-72 and 0-73 (table 4) the proportion of hatched eggs was reduced to 9.6 per cent and 1.8 per cent, respectively. A 2 per cent solution has a decided caustic effect which is particularly noticeable if the material is allowed to remain on the bare skin of one's hand. No experiments were conducted with this material on trees during the dormant season; consequently, its effect is unknown.

Pyridine (10 cc.) combined with xylene (10 cc.) and resin (enough to make 25 cc. of solution) is a very effective mosquito larvicide, so this mixture was given a trial. In experiment 0-78 (table 4) where the above mixture was used at the rate of 2 parts to 98 of water plus enough soap to make the spray spread well,

there was little or no reduction in the percentage of hatch. This solution was also mixed with lime-sulfur (G-16, table 4) with no apparent change in the results. It was also combined with crude carbolic acid (exp. 0-79, table 4) at the rate of 1 part of each to 100 cc. of soapy water, and the percentage of hatch was reduced to 13.3 per cent. This decided decrease was unquestionably due to the crude carbolic acid. The pyridine mixture is highly volatile and this may account for its ineffectiveness.

SUMMARY

In the summary only the new and important features of this investigation will be considered.

A morphological study of the eggs of three apple plant lice *A. avenæ*, *A. pomi* and *A. sorbi* shows two distinct layers in the egg shell, an outer semi-transparent layer which is soft and glutinous when the egg is deposited, but hardens and becomes somewhat tough (may be brittle) and impervious upon long exposure to weather, and an inner soft, elastic, membraneous, black layer. A third layer thin and membraneous, may be seen about the nymph when it starts to emerge. This skin is probably the first exuvium, since it is shed by the nymph as it emerges.

Under out-of-door conditions the outer layer of the egg usually splits along the dorso-mesal line a number of days (2 to 30 or more for *A. avenæ)* before the nymph emerges. So far as observed under greenhouse conditions the eggs of all three species split their outer covering at least a few hours before the pigmented layer is severed. In 1918 the first eggs of *A. avenæ* with split outer coverings were seen on February 15, and when the first nymphs emerged, on March 21, approximately 95 per cent of the normal live eggs (45-50 per cent of the eggs were dead) had split their outer semi- transparent covering.

These observations on the morphology and behavior of the egg coverings show conclusively that the egg is not a hard resistant body, and that it goes through a critical change previous to the emergence of the nymph. It is in the midst of this critical period that the egg is most susceptible to evaporating factors and certain contact insecticides.

The outer semi-transparent layer of the egg is somewhat impervious to water; consequently, the water content of the embryo does not undergo very much evaporation in moist weather, or in other words, when low evaporating factors exist, such as high humidity, low temperature, and probably small wind velicity. The outer layer, however, is not entirely impervious, for extreme drought

will cause the vast majority of the eggs to shrivel and never hatch. In other words, low humidity, high temperature and probably air velocity undoubtedly bring about a greater evaporation of the water content of the embryo, and thus destroy the living form.

The inner pigmented (black) layer of the egg is not an efficient protector against evaporation. Numerous and varied experiments at the laboratory and observations made on the percentage of hatched eggs of *A. avenæ* during the past two totally different seasons, 1917 and 1918, show conclusively the pervious nature of this layer.

The eggs are most susceptible to evaporating factors and contact insecticides during the latter part of March, or in other words, when the greatest number show a split outer layer, and this occurs when the first nymphs start to emerge (fig. 7 and 10).

Experiments conducted in the laboratory under controlled percentages of moisture and also experiments where similar eggs of *A. avenæ* were kept out-of-doors during the critical period (February 15 to March 31, and especially important March 15 to March 31) in 1917 which was wet, while in 1918 this period was dry, show quite conclusively that the percentage of hatched eggs is much higher in a low evaporating environment than in a high evaporating medium.

Contact insecticides probably prevent the egg from hatching in several ways. From a physical viewpoint some substances tend to harden the outer semi-transparent shell (lime-sulfur), and this makes it impossible for the nymphs to split the hardened layer. This hardening effect may be due to dessication. Dessicating substances may also remove the water content of the embryo within, especially if applied after the outer layer has split. Other substances soften and disintegrate the outer impervious layer (crude carbolic acid and cresols) and thus expose the inner pigmented layer to evaporating factors. The above physical reaction of contact insecticides on eggs of aphides may be important, but it is probable that the toxic effect upon the embryo of various contact insecticides is more important. So far, no technic has been found which will determine the penetrative ability of the various chemicals used.

CONTROL MEASURES

In conclusion to the foregoing experiments and observations we can safely recommend as a control measure for aphids a delayed dormant spray of lime-sulfur, 1-8 or 1-9, combined with nicotine ("Black-leaf 40"), 1-500. The combined spray kills 98-100 per cent of all the eggs that are coated and will also kill all the newly-hatched nymphs, provided they are hit with the spray. Dormant

lime-sulfur 1-9 by itself will kill a large percentage (90 per cent or better) of the eggs, but not enough to rely upon it alone. Furthermore, lime-sulfur alone will kill only a small percentage of the newly-hatched nymphs if they have made their appearance. Therefore, a combined spray is better, for it will kill a greater percentage of eggs and all the nymphs.

The time of application is important. In the foregoing discussion on the behavior of the outer layer of the egg it was shown that the egg is most easily killed when the outer shell has split (plate 1, fig. 2-5) and the greatest number of eggs show a split outer shell when the nymphs are emerging. With these facts in mind one can get the best results by delaying the dormant spray until the fruit buds start to swell and when they first show green. At this stage the eggs of the oat aphis *A. avenæ* will be hatching while the eggs of the rosy aphis, *A. sorbi*, and the green apple aphis, *A. pomi*, will not hatch for 7 to 14 days later. The dormant spray will not injure swollen fruit buds (plate 2, fig. B) or those showing short projecting tips of leaves (plate 2, fig. C), while a dormant spray applied when the leaves are distinct and separated (plate 2, fig. D) will burn the foliage of most varieties. Also, the recently-emerged nymphs of the aphides will conceal themselves to a large extent between the separated leaves, and it will be impossible to hit all of them with a contact spray.

A miscible oil, "Scalecide" 1-5, has been given a thorough trial in the orchard and at the laboratory, but it has not produced satisfactory results. Some eggs are killed by "Scalecide" and other miscible oils, but we have not used any which give as good control as a combined lime-sulfur and nicotine spray. Miscible oils containing derivatives of carbolic acid give more perfect control than those which do not possess the same; however, there is some indication that an amount of acid (2 per cent of the spray) sufficient to kill all the eggs may be detrimental to dormant buds.

Other contact sprays, such as a strong solution of fish-oil soap, combined with nicotine 1-500 or crude carbolic acid 1.5 to 2 per cent, give considerable promise of becoming effective sprays for the control of aphides in the egg stage when applied near the time when the nymphs emerge. These studies are as yet in the experimental stage, consequently, we cannot recommend the treatments for orchard spraying. Any soap spray spreads better than lime-sulfur, and for this reason they may prove to be more efficient. Crude carbolic acid or cresol U. S. P. combined with fish-oil soap will not injure dormant buds, so far as observed.

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